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Methodology for the conduct of a seismic risk mitigation study.

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NAVAL POSTGRADUATE SCHOOL
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THESIS

METHODOLOGY FOR THE
CONDUCT OF A
SEISMIC RISK MITIGATION STUDY

by

Mark David Huntzinger

June, 1985

Thesis Advisor: P. M. Carrick

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Methodology for the Conduct of a Seismic Risk Mitigation Study

by

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Submitted in partial fulfillment of the requirements for the degree of

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The author presents a methodology for evaluating the seismic vulnerability of a bases facilities. The methodology starts with the determination of the "mission important" facilities to a base, the foundation of which is the importance of the missions they house. The results of which are used to determine the facilities that should be studied for their seismic vulnerability under contracts administered by Naval Facilities Engineering Command Engineering Field Divisions. The methodology presents alternatives for evaluating the results of the engineering and seismic studies, culminating in a rank ordering of the seismic upgrading projects developed by these studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The Department of the Navy has numerous bases in active seismic regions of the world. The missions of the Navy are such that basing in these areas of active or potentially active seismic regions is unavoidable.

Each base resembles a small city, containing major industrial and residential areas. The replacement value of the structures alone is estimated in excess of $25 billion. The Navy has a military construction budget of about $200 million for new structures in these seismically hazardous regions. Adding the investment in equipment and people the potential loss in dollar terms from seismic activity is tremendous. Added to this and of more significance is the loss of mission capabilities. The realization that buildings or facilities exist only to support a base's mission is important to the concept of this thesis. [Ref. 1: p. 1]

The Navy is investing in engineering and seismic studies to evaluate the vulnerability of the shore establishment to seismic damage. The evaluation of the findings of these engineering and seismic studies is left up to the individual base studied. This thesis presents a methodology for the base to use in directing and evaluating the findings of the engineering and seismic studies. Such a base evaluation is titled a Seismic Risk Mitigation Study.

Directing the engineering and seismic studies is an important portion of a Seismic Risk Mitigation Study. With an evaluation of the bases facilities for mission importance, the engineering studies to evaluate the potential for seismic damage can be directed to the facilities that are most important to the performance of a base's mission. With such direction, funds would not be spent evaluating facilities that provide little to the accomplishment of a base's mission.

The research question posed and answered by this thesis is: How should the results of the engineering and seismic studies best be evaluated at the base level?

The outline of the basic methodology presented in this thesis is contained in Figure 1.1. A Seismic Risk Mitigation Study starts with a realization that the potential for loss of mission capabilities from seismic hazards exist. A study is ordered and a study group formed to conduct the Seismic Risk Mitigation Study. The first phase of the study is determining the missions of the base and determining what facilities are required to perform the missions. From the evaluation of the missions a base's facilities are classified into one of five categories, called facility types. The base commander approves the classifications of the facilities. The next step involves directing and examining the engineering and seismic vulnerability studies. Directing the engineering vulnerability studies concerns using the facility type classifications to determine which facilities should be investigated. The engineering and seismic vulnerability studies and other information are examined to determine the replacement cost, seismic risk reduction cost and the probable damage estimates for each facility. Finally, these costs are used to determine a rank ordering of the facilities within each category. The rank ordering indicates which seismic risk reduction projects would have the highest return per dollar spent on a project to upgrade the facility. The result of the Seismic Risk Mitigation Study is this rank ordered listing of upgrading projects. With the results of the study the base can most effectively invest funds to reduce the identified seismic hazards. Two

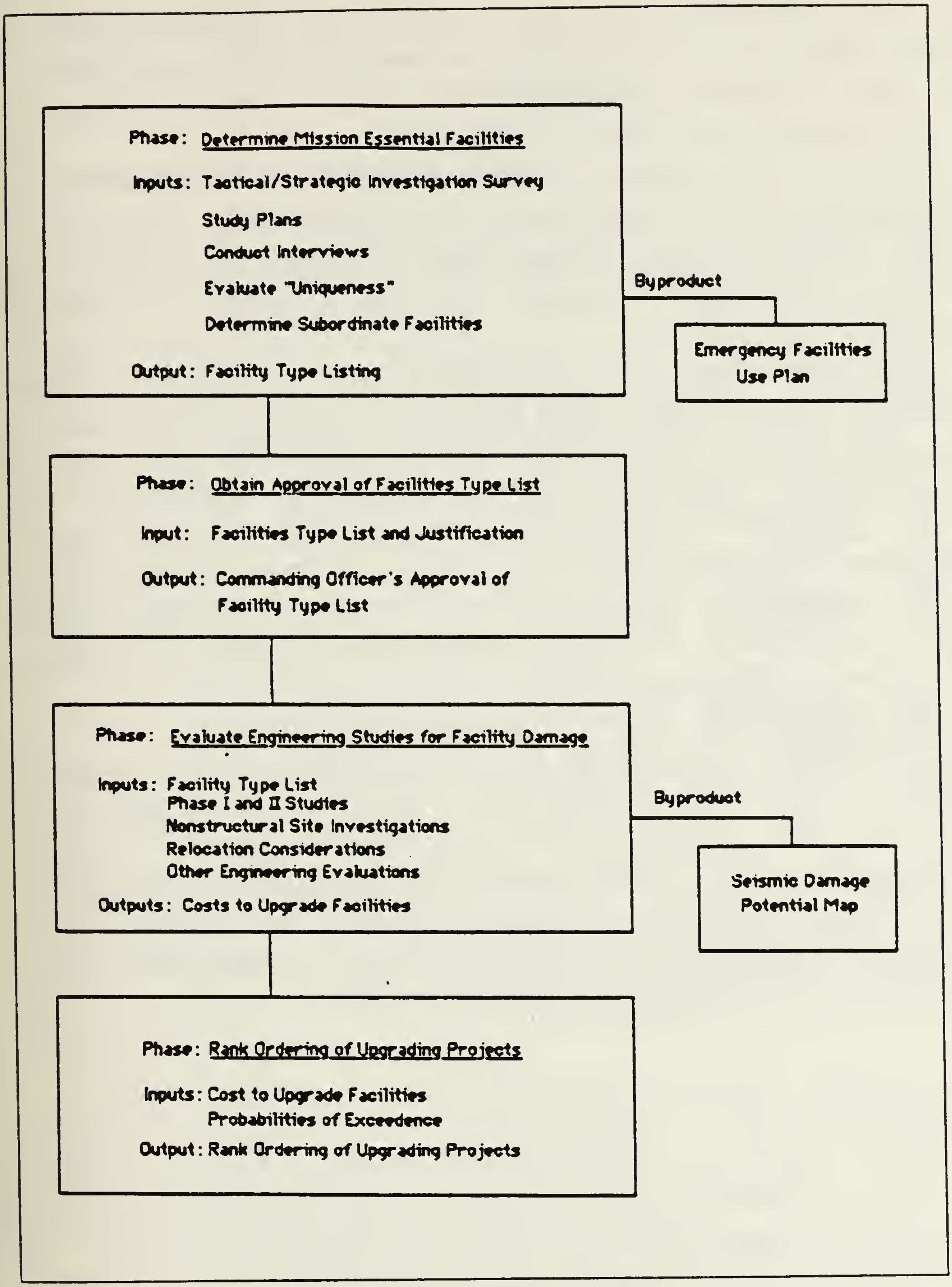


Figure 1.1 Seismic Risk Mitigation Study Steps.

important by-products of the conduct of a Seismic Risk Mitigation Study are inputs for an Emergency Facilities Use Plan and a Seismic Damage Potential Map. Both of these by-products are explained in appendices.

This study is based on participation in a test Seismic Vulnerability Study at the Naval Air Station (NAS), Moffett Field, California by the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California and a review of the pertinent literature.

The methodology for the conduct of a Seismic Risk Mitigation Study as presented herein has not been applied in any test case. The Moffett Field test study has not progressed past the translation of missions to facilities phase. The survey results are presented in NCEL Technical Memorandum TM-51-84-09 [Ref. 1]. The determination of the mission essential facilities as determined during the Moffett Field test study will be presented in NCEL Technical Memorandum TM-4566 [Ref. 2].

The methodology represents a reasonable effort to best use the information provided by the engineering and seismic studies. The actual conduct of a Seismic Risk Mitigation Study is not intended to be performed by engineers or seismologists, but by base personnel knowledgeable about the base and its missions. Certain processes may require an engineering evaluation. Where required, suggestions for obtaining these evaluations are presented.

II. BACKGROUND

A. NATURE OF THE EARTHQUAKE THREAT

The threat of damage and loss of life due to earthquakes and related phenomena is great. Many areas of the world are known for their high seismic activity. Japan is said to have a measurable earthquake every day. The San Andreas Fault is famous as a highly active earth fault. The general threat of damage from earthquakes and specific applications to Naval installations are shown in Table I It is important for the reader to understand the widespread devastation which could occur from an earthquake. Because the Continental United States has not experienced a recent devastating earthquake, the following paragraphs will summarize the types of possible damage.

The most damaging manifestation of the earthquake threat is the actual ground shaking or movement causing the collapse of buildings with a loss of life of those trapped in or under the wreckage. Structural damage from ground shaking can range from merely cracked plaster to total collapse. Ground shaking provisions have been incorporated into design codes and construction techniques to reduce the damage potential. They do so by providing required strength and ductility to absorb the energy transmitted to the site in the form of ground vibration.

Ground shaking, even with good seismic structural design, can cause nonstructural damage. This is damage caused by and to the furnishings of a building, or its mechanical and electrical systems. A file cabinet, computer or inventory overturning due to an earthquake are all examples of nonstructural contents damage. Even in the best

TABLE I

Earthquake Hazards

<u>Main Earthquake Hazards</u>

A. Ground Shaking
   Ground Displacement
   Soil Liquefication
   Differential Settlement
   Land and Mud Slides

B. Tsunamis
   Floods from Dam and Levee Failure
   Retaining Wall Failure

C. Fires

<u>Secondary Effects</u>

1. Chemical or Hazardous Material Spills,
   Tank Rupture

designed buildings, nonstructural damage can cause the interruption of operations being performed in a building. This is an important concept in the study that follows.

Ground movement can also cause surface faulting, rifts or lateral displacement. Faulting or rifts are separations or cracks in the ground causes by soil settlement, sliding or other causes. Lateral displacement is the movement along a fault, resulting in offsets to roads, streams or structures that bisect a fault; photographs show the offset caused by the movement along the fault. During the 1906 San Francisco Earthquake (Richter magnitude 8.0) the horizontal displacement along the fault was up to 21 feet. Roads, runways or utilities bisecting a fault could be sheared if displacement occures. [Ref. 3: p. 12]

Specific threats from ground shaking and displacement to Naval installations are similar to seismic hazards faced in other active areas. The age of the building has much to do with the designed seismic resistance. Many Navy buildings were designed and built without the benefits of the current knowledge of structural performance. The age and construction quality of the buildings are factors in the current seismic resistance. The nonstructural hazards of the contents are present primarily from the lack of bracing or anchorage of nonstructural items.

Seismic activity can lead to high ground pore water pressure and ground settlement, technically known as soil liquefication. Soil liquefication is in essence, a quicksand like condition which under shaking can lead to soil settlement or lateral sliding of massive portions of ground. Soil liquefication is most probable in waterfront areas with high water tables where the soil composition is loose sands or fill material. Unfortunately, this is the condition that exists at most Naval waterfront installations. Soil liquefication can cause damage to piers, quay walls, buildings, drydocks, utilities systems, roads and runways. Differential settlement is also possible, primarily from variation in the underlying sediments.

Land and mud slides are well known problems in parts of California. They can occur by seismic causes or nonseismic causes such as ground water fluctuation. Areas that are prone to sliding generally are identifiable, but methods to reduce the threat may not be easily accomplished. In areas of generally unstable soil, such as California, the traditional methods of slope reinforcement have had limited success. Seismically induced sliding most likely would challenge ordinary slope reinforcement efforts. The best method to reduce the hazards from sliding is not to build on or in a slide prone area. Mapping of the potential slide and affected areas can reduce the hazard by not having people or facilities in the hazardous area. Sliding can also occur underwater, submarine sliding can create problems for ships by reducing the channels to the point the channels do not provide the necessary depth for ships to pass.

Tsunamis are seismically induced high amplitude sea waves. Tsunamis are a unique indirect product of earthquakes in that the causative event may be hundreds of miles away from the damaging effect of the Tsunami striking a coastal area. The Great Alaskan Earthquake of 1964 (Richter magnitude 8.3) produced a tsunami that caused 119 deaths in Crescent City, California. The wave that caused the damage was estimated at nine feet. For waterfront structures and Naval installations tsunamis are especially worrisome because of the damage potential they have. Tsunamis have three areas of potential damage, first is the overtopping of dikes or retaining walls causing flooding or damage to structures. Next is the affect of the wave "draw down" and "run up" on ships, piers and waterfront structures. A tsunami wave has a "draw down" or lowering of the water level equal to the "run up" or height of the wave. These differences in water level can cause damage to ships by their striking bottom, piers by the strain of the moored ships first downward and then upward. There would not be time to adjust the mooring lines between the "draw down" and the "run up". Waterfront structures, such as quay walls, are susceptible to collapse as their design is dependent on the hydrostatic pressure of the water. Without the water pressure during the "draw down" the possibility of collapse on old or poorly designed waterfront structures is great.

The final area of damage from tsunamis is in the unusual or extrastrong currents caused by the influx of the extra water in the waves. These currents can cause damage to waterfront structures. [Ref. 4]

Seismically induced failures of dams or levees can cause significant loss of life or property damage. The cause of the failure may be any of the reasons mentioned above but the potential damage can be much more severe simply due to the inundation by water such as would be expected by a dam failure.

The fire hazards are often overlooked when evaluating earthquake hazards. More property was lost from fires following the 1906 San Francisco Earthquake than by the direct shaking of the earth [Ref. 5: p. 109]. The threat today is somewhat reduced by the use of improved construction materials and construction practices but the potential for damage is still great. The shaking may also cause interior wiring to break exposing wires that can short and cause a fire. Exterior electric distribution networks may fail and cause shorting, fuel storage or fuel distribution networks may rupture due to the ground shaking providing the fuel for the fire. Ground shaking may cause breaks in the water distribution system, reducing the fire fighting capability. The possibilities for fire exist, without a ready source of water the fire fighting efforts are hindered, thereby leading to an unacceptable level of damage due to fire. Methods to decrease the hazards from fire are the seismic strengthing of the water distribution system, and the utilities and fuel systems.

Finally, there are hazards associated with the storage and handling of chemicals or hazardous materials. Seismically caused overturning of chemical or hazardous containers can lead to a hazardous vapor cloud. The first indication of a problem may be the death of a person involved in the recovery effort. Methods to reduce this hazard include separation of the storage of chemicals so accidental spilling will not create a hazardous mixture, and restraints on storage bins or cabinets.

The severity to which the hazards exist depends on the magnitude and proximity of the earthquake. The closer to the epicenter or the greater or longer the shaking the more damage can be expected. The extent of the earthquake threat to a specific area is found through the use of Seismic Risk Maps.

B. SEISMIC RISK MAPS

Figure 2.1 is the Department of Defense Seismic Zone Map of the United States [Ref. 6: p.3-13]. Seismic Zone or Risk Maps are derived from historical occurances of earthquakes, but do not consider local physical conditions or earthquake return times. The maps present a rough idea of the long term earthquake hazard for an area. No common time scale is implied. A major earthquake would not be expected to occur as frequently in an East Coast Zone 3 as in a West Coast Zone 3. The Department of Defense Seismic Zone Map has five zones (0 to 4). The difference in the number and general delineation of the seismic zones is necessary for the designing the lateral resistance of a building and is used in the assigning of a facility construction design coefficient, or safety factor, as prescribed by Reference 6. The intent is to generally identify the seismic potential for the areas of the world. The greater the zone number the greater the history for damage in that area and the greater the need for more structural resistance in buildings. For each zone there is a approximate level of shaking which might be expected during the life of a facility. These levels can be described by the Modified Mercalli Scale of

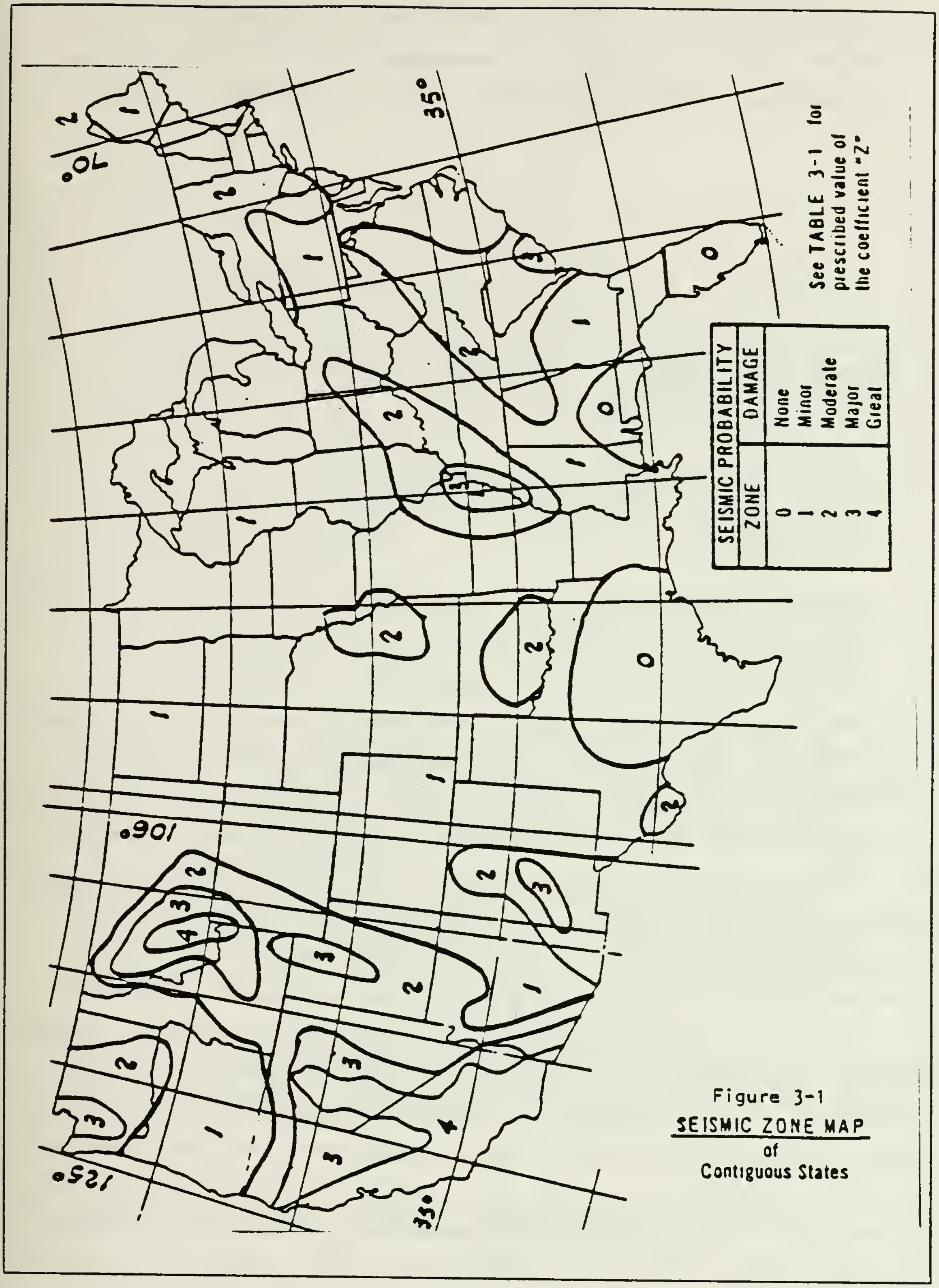


Figure 2.1 Seismic Zone Map.

Earthquake Intensity. The correlation is shown in Table II with Table III provi ıg a description of the Modified Mercalli scale. [Ref. ⁄: p. 11]

TABLE II
Seismic Zone to Mercalli Intensity Correlation

Seismic Risk Zone		Modified Mercalli Intensity
0	-	I-IV
1	-	V-VI
2	-	VII
3 and 4	-	VIII and Greater

The expected future seismic activity for a specific site can be found through an evaluation of the historical occurances of earthquakes in the region containing the site and an evaluation of the available geologic data for the site. An automated computer program for performing seismic analyses of these types is contained in NCEL Technical Report R-885 [Ref. 8].

Earthquakes can be measured in terms of intensity (damage effects at a given distance from the source) and magnitude (a release of a given energy amount). The intensity of an earthquake is measured using the Modified Mercalli Scale (Table III). The measurement is in terms of earthquake effects, and is either descriptive or quantitative. Intensities are measured based on the human senses and are used to describe the effects of the earthquake in different areas near the epicenter. Plotting

TABLE III

Modified Mercalli Scale of Earthquake Intensity

I	Not Felt
II	Felt by persons at rest, on upper floors, or favorably placed.
III	Felt indoors. Hanging objects swing. Vibrations like passing of light truck.
IV	Hanging objects swing. Vibrations like passing of heavy trucks; or sensation of a jolt. Standing automobiles rock. Windows, dishes, doors rattle. Glasses clink. Wooden walls and frames may creek.
V	Felt outdoors; direction estimated. Sleepers awakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors, shutters, pictures moved.
VI	Felt by all. Persons walk unsteady. Windows, dishes, glassware broken. Knicknacks, books, etc. fall off shelves; pictures off walls. Furniture moved or overturned. Weak plaster and average-quality masonry cracks. Small bells ring (churches, school). Trees, bushes shake.
VII	Difficult to stand. Noticed by drivers of automobiles. Hanging objects quiver. Furniture broken. Damage to weak masonry. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tile, cornices, etc. Waves on ponds; water turbid with mud. Small slides and caving-in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII	Steering of automobiles affected. Damage to average masonry; partial collapse. Some damage to good, partially reinforced masonry; none to good, fully reinforced masonry. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundation if not bolted down; loose panel walls thrown out. Branches broken from trees. Changes in flow or temperature of springs or wells. Cracks in wet ground and steep slopes.
IX	General panic. Weak masonry destroyed; average masonry heavily damaged, some with complete collapse; good, partly reinforced masonry seriously damaged. Frame structures, if not bolted, shifted off foundations. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.
X	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown onto banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI	Rails bent greatly. Underground pipelines completely out of service.
XII	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

of the intensities are done using isoseismal lines on an isoseismal map. [Ref. 9: p. 43]

Magnitude is a computed rating obtained from interpretations of seismograph readings. The inventor of the magnitude scale, Charles Richter defines the scale as follows:

> "Magnitude is intended to be a rating of a given earthquake independent of the place of observation. Since it is calculated from measurements on seismograms, it is properly expressed in ordinary numbers and decimals. Magnitude was originally defined as the logarithm of the maximum amplitude on a seismogram written by an instrument of specified standard type at a distance of 100 kilometers (62 miles) from the epicenter...Because the scale is logarithmic, every upward step of one magnitude means multiplying the recorded amplitude by 10...The largest known earthquake magnitudes are near 8.75; this is a result of observation, not an arbitrary 'ceiling' like that of the intensity scales." [Ref. 3:p. 70]

C. FEDERAL EARTHQUAKE HAZARDS REDUCTION

The Earthquake Hazards Reduction Act of 1977 (Public Law 95-124) has as its purpose the reduction of the risks to life and property from earthquakes through the establishment and maintenance of an effective earthquake hazards reduction program.

The general issues Congress outlined in implementing the program to reduce earthquake hazards are:

1. Preparedness and response planning.
2. Earthquake prediction and warning.
3. Earthquake hazards reduction through construction programs.
4. The role of private and public financial institutions.
5. Land-use planning and its implementation.
6. Communication and education.

[Ref. 10: p. 19]

Preparedness and response planning is concerned with evaluating the pre-earthquake (or disaster) recovery planning efforts of federal, state and local governments and the post-earthquake hazards reduction and recovery planning. Thirty-nine States are wholly or partially located in areas of high or moderate seismic risk. The potential for loss of life, destruction of property and economic disruption caused by earthquakes is significant. Preparedness and response planning at all levels of government can reduce the impacts of earthquakes. The intent of the planning and response planning issue is to encourage the preparedness of governments, to coordinate the efforts of the various levels of governments, and to ensure the reduction of the loss of life and property by effective recovery efforts.

Earthquake prediction and warning issue is concerned with developing an effective method to predict earthquakes, warn the population at risk and address the social and economic aspects of such a warning. Some scientific effort is being expended to develop a method for predicting earthquakes. The reduction of earthquake hazards to human life is possible with evacuation from the predicted affected area. A few hours warning can significantly reduce the loss to human life with an effective evacuation policy. Notice of months or years can significantly reduce the hazards to buildings by allowing time to strengthen the building. Prediction currently is not an exact science and even when it does become exact the problems with the prediction itself need to be examined. If an area is predicted to have a major earthquake in a year, the economic aspects of businesses leaving, etc. may cause untold economic panic. Homeowners would try to sell property or gain earthquake insurance. Insurance companies would not issue policies or charge uneconomical rates. The impacts of predicting an earthquake on the community are a major concern in the study of this issue.

Earthquake hazards reduction through construction programs is probably one of the easiest to define and implement. Building codes for new construction can, and in certain areas have, been designed to provide a building that provides seismic resistance. The basis of the building codes for the State of California and the Department of Defense is influenced by seismic potential levels. New construction can protect against the loss of life by implementation of semisically current state of the art design provisions in building codes. Upgrading existing buildings to reduce seismically induced hazards is conceptually simple, evaluate the building and rebuild to reduce hazards by providing increased seismic resistance. The problem with upgrading existing buildings is with the costs of evaluation and rebuilding. Again, action by government could force hazards reduction through mandatory upgrading of existing buildings.

The role of private and public financial institutions in reducing earthquake hazards is not easy to define. The impacts on financial institutions of a damaging earthquake are potentially fatal. If a bank has many mortgages in an area destroyed by an earthquake the collateral for those loans is potentially worthless. Earthquake insurance claims after an earthquake could bankrupt a insurer. With the advent of earthquake prediction the defaulting on loans by businesses leaving the area or homeowners is a great possibility. These and other impacts on the financial institutions are the basis of study in this area.

Land-use planning and implementation is another conceptually easy hazard reduction issue. Restricting the building near active faults, on unstable soils, or in generally seismically unsafe areas can reduce the hazards that otherwise could be present. It would seem that only a fool would build on or near an active or known earthquake fault, but it happens. Daly City, California sits astride the famous San Andreas Fault. In fact a housing development was built astride the fault in Daly City in the 1960's. Identification of seismically hazardous areas is continuing, governments actions to restrict the use of these areas are the concepts under study.

Communication and education is simply providing information to the population on the hazards from earthquakes. General and specific information is required and needs to be presented in such a way as not to create a doomsday attitude. Seismologists predict a major earthquake will occur in the San Francisco area every 100 years. As the last major earthquake was in 1906, the probability of the next major earthquake becomes greater as time progresses. [Refs. 7,10: pp. 14, 20-67]

Congress has recognized the need to reduce the potential hazards from earthquakes, and has provided funds, to study the issues outlined above. The efforts of the Department of the Navy will be examined next.

D. DEPARTMENT OF THE NAVY EARTHQUAKE RELATED PROGRAMS

The Navy has a significant earthquake problem. The worldwide basing of the Navy has required the location of naval bases in seismically active or risky areas. The investment in structures at the shore activities in these areas is estimated to be $25 billion. [Ref. 1: p. 1]

While the Department of the Navy has no formal earthquake programs, several programs are earthquake safety related. These programs include: expedient measures to reduce earthquake hazards; dam inspections; drydock inspections; seismically influenced building designs; facilities inspections; and research and development.

The expedient measures to reduce earthquake hazards were directed by Naval Facilities Engineering Command Instruction 11012.141 [Ref. 11]. This instruction recommended actions to be taken to reduce earthquake hazards. The actions are largely quick fix methods to secure nonstructural components, utilities or equipment. The methods are generally inexpensive fixes designed to prevent seismically induced failure of the components. Typical fixes include anchoring transformers to prevent their overturning or laterally restraining non-load bearing partitions.

A portion of the dam inspection programs is concerned with evaluating the possibility of seismically induced failure of Navy and Marine Corps owned dams in seismic zones 3 and 4. Upgrading projects are required whenever seismic deficiencies are found. [Ref. 12]

The drydock inspection and certification program is similar in nature, a great investment in facilities, mission capabilities and ships could be lost in the event of seismically induced failure. This program required inspection of all drydocks and the development of upgrading projects where deficiencies were found. Seismic resistance considerations were an important part of this inspection program. [Ref. 13]

The seismically influenced building design program was the issuance in 1974 of a standard criteria, or design code, for seismic design for all Department of Defense structures. The basis of this criteria was the criteria published by the Structural Engineers Association of California. The same criteria is the basis for the building and design codes of the State of California. Since 1974 all DOD structures worldwide have been designed using this same seismic criteria. Adjustments for the building location and intended use are made through the use of design factors. The seismic risk zone maps provide one design factor, providing a stronger seismically resistant building in zone 4 than in zone 0. Another design factor is influenced by the intended building use. A distinction is made between essential facilities, high risk facilities and all other facilities. Table IV is an explanation of the distinction between the facility types. The distinction between facility types is necessary to provide another design factor. This design factor provides a stronger building for an essential facility than for a high risk facility.

The design criteria is intended to design structures that will:

1. Resist minor earthquakes without damage.
2. Resist moderate earthquakes without structural damage, but with some nonstructural damage.
3. Resist major earthquakes, of the intensity of severity of the strongest experienced in California, without collapse, but with some structural as well as nonstructural damage.

[Ref. 6: p. 2-4]

The facilities inspection program was developed to evaluate the seismic resistance in existing Naval facilities. Reference 14 required a seismic investigation be conducted in conjunction with any construction project to modernize, rehabilitate or provide major repairs where the cost of the project is $100,000 or 10% of the replacement cost of the structure. The purpose of the seismic study was to evaluate the structure for possible seismically caused life safety hazards which then would be included in the project for elimination. Reference 15 recommended base wide seismic safety studies but provided no funding to accomplish them. In 1977 the Naval Facilities Engineering Command instituted a series of engineering and seismic field studies

TABLE IV

Types of Facilities

ESSENTIAL FACILITIES

Houses a Critical Facility Necessary for Post-Disaster Recovery and Require Continuous Operation During and After an Earthquake

- Hospitals
- Fire Stations
- Rescue Stations
- Garages for Emergency Vehicles
- Power Stations
- Emergency Utilities
- Mission Essential Communication Systems
- Facilities involed in Operational Missile Control, Launch, Tracking or Other Critical Defense Capabilities
- Facilities involved in Handling, Processing or Storaging Sensitive Munitions, Nuclear Weaponry or Processes, Gas and Petroleum Fuels, and Chemical or Biological Contaminants.

HIGH RISK FACILITIES

Primary Occupancy is for Assembly of a Large Number of People

- Auditorium
- Recreation Facilities
- Dining Hall
- Commissary

(Auditorium, Recreation Facilities, Dining Hall, Commissary) - Occupancy > 300 People

- Confinement Facility
- Central Utilitys not considered Essential
- Buildings having High Value Equipment requires agency justification

ALL OTHER FACILITIES

All Facilities Not Mentioned Above

to assess the seismic vulnerability of entire Naval bases. These studies are administered through the Engineering Field Divisions and are to be conducted at all Naval installations in DOD seismic zones 3 and 4. These base wide studies are called Phase I studies and are to be performed at 92 Naval Bases worldwide. Table V is a listing of the bases or geographic areas where the Phase I studies are to be performed, by Engineering Field Division. [Ref. 16]

About 70% of the Phase I studies are completed at this time [Ref. 1: p. 1]. The Phase I study provides findings on the facilities studied, and geotechnical and seismic hazards of the base. The facilities findings are based on a rapid analysis technique developed by the Naval Civil Engineering Laboratory [Ref. 17]. The facility findings indicate anticipated structural responses under differing seismic loadings. Appendix B contains a sample facilities report. The geotechnical and seismic hazards section of a Phase I study present findings on the geological, seismicity and ground motion evaluations of the base. Specific hazards associated due to ground displacement, soil liquefication, tsunamis, etc. are addressed in this section. basic information to the base on the anticipated structural response and possible damage to the facilities studied.

The Phase I studies did not evaluate every facility on the base. The criteria for evaluation under a Phase I study are that it be:

1. Built prior to 1974. (The assumption is that all facilities built after 1974 were built using the new design criteria.)
2. Be over 3,000 square feet in floor space.
3. Have a replacement cost of over $100,000.
4. Be able to be rapidly analyzed. (The engineering technique used to evaluate the structures has limitations in applications.)

TABLE V

Phase I Study Locations

Northern Division

NAS, South Weymouth, MA

Southern Division

Charleston, SC;	Parris Island, SC;
Beaufort, SC;	Memphis, TN

Atlantic Division

Sabana Seca, Puerto Rico
Roosevelt Roads, Puerto Rico

Western Division

Nuclear Power Training Unit, Idaho Falls, ID;
Naval Radio Station, Jim Creek, WA;
NAS, Whidby Island, WA;

Keyport, WA;	Seattle, WA;
Bremerton, WA;	Bangor, WA;
Skaggs Island, CA;	Stockton, CA;
Oakland, CA;	Concord, CA;
Treasure Island, CA;	Alameda, CA;
Mare Island, CA;	Monterey, CA;
NAS, Moffett Field, CA;	Lemoore, CA;
Point Sur, CA;	Pacific Beach, CA;
Centerville Beach, CA;	San Diego, CA;
China Lake, CA;	Port Hueneme, CA;
Point Mugu, CA;	El Centro, CA;
Long Beach, CA;	Seal Beach, CA;
Camp Pendleton, CA;	Barstow, CA;
El Toro, CA;	Twenty-Nine Palms, CA;
Yuma, AZ;	Adak, AL;
Point Barrow, AL	

Pacific Division

Guam;	Phillipines

5. Be selected for evaluation based on occupancy or mission importance, as determined by base personnel. The determination of what facilities should be evaluated should be based on the importance of the

facility to the base. The methodology presented herein aids in making these facility importance determinations.

The structures analyzed under the Phase I studies were to be evaluated under three possible earthquake conditions, a 50 year, 100 year and 225 year return time earthquakes. While the Phase I studies used specific Peak Ground Acceleration (PGA) "g" (gravity) forces in their calculations based on the base location, etc. the return times correspond to the PGA "g" forces that can be expected in earthquakes of these return times. [Ref. 17] The expected PGA "g" forces were determined using automated techniques such as that described by NCEL Technical Report R-885 [Ref. 8]. These automated techniques use information on the geological and known seismic hazards near the base to estimate the PGA's expected. Simply stated a return time of 50 years is an earthquake of such a magnitude that it will only happen once in 50 years. By this simple definition a 225 year earthquake will be much more severe than a 50 year earthquake, as a 225 year earthquake will occur only once in 225 years. For example, the estimated Richter value for earthquakes along the San Andreas Fault in the San Francisco area are estimated at:

50 year return time 7.0
100 year return time 8.0
225 year return time 8.3
[Ref. 18]

Facilities which the Phase I study indicates anticipated damage of over 30% are to be evaluated under a follow on engineering study called Phase II studies. Phase II studies consist of a detailed engineering evaluation to predict the actual extent of seismically induced damage. The Phase II study will also provide a plan and cost estimate to structurally upgrade the facility and a cost estimate to reduce nonstructural hazards. Appendix B contains Phase I and II facility reports. [Refs. 19,20]

The research and development programs include projects under study by NCEL and recommendations of the Navy Earthquake Risk Reduction Panel. The NCEL projects include the development of the Rapid Analysis Technique used for the Phase I studies and other projects. The Navy Earthquake Risk Reduction Panel was commissioned by the Office of Naval Research in 1984 to conduct an overview of the earthquake programs run by the Navy and makes recommendations on the future areas of effort. The panel is comprised of seismologists, geologists and engineers from academia, Navy commands and the U.S. Geological Survey.

One of the recommendations of the panel was that the Phase II studies be assigned on the basis of the mission importance of the facility or system [Ref. 21]. The current criteria for selection of facilities to be evaluated by the Phase II studies is up to the discretion of the Engineering Field Division administering the contract. In some cases the Phase II studies evaluated World War II era temporary structures. The study methodology presented in this thesis is to determine the most important facilities to a base, in part a response to the panels recommendation.

The process of performing a Seismic Risk Mitigation Study will identify the facilities that are most important to the performance of the base's missions. Using this information the Phase II studies can be directed to include the most important facilities. Such direction will ensure the funds spent on the Phase II studies will return the most benefit to the base.

E. DEFINITIONS

In the procedures that follow, several terms or concepts are used that require definition. The definitions are as follows.

1. Facility

A facility is a structure or system. Buildings, roads, runways, electrical distribution systems, telephone systems, etc. are all examples of a facility for purposes of this study. A facility can be comprised of one building or be comprised of a series of buildings, tanks, lines, etc. At times a system will be described as a complete facility, but where ever possible the system should be broken into uniquely identifiable portions. For example, if the fuel system is described as being "Mission Essential", the system should be evaluated to determine exactly what portions are most important to the performance of the mission and which portions are secondary to the mission. The most important portions are then further evaluated.

2. Mission Essential

The output of the study is a listing of base facilities by descriptive terms as "Mission Essential", etc. The term "Mission Essential" is used to highlight the relative importance of the facilities so designated. The importance of the facility is in terms of the missions being performed therein. The intent is not to downgrade the facilities not labeled as "Mission Essential". Throughout the study a numbering system tied to a facility function description is used to avoid the inherent bias of the term "Mission Essential". The term "Mission Essential" is only applied when the facility lists are presented to the Commanding Officer or study authorizing officer, to highlight the importance of these facilities over the others based on the intentions of the study.

3. The Base

The base is the Naval installation under study. The physical definition of the base can be complicated by the presence of other Naval activities in the area. The definition of the base in San Diego could be the entire Naval complex-Submarine Base, North Island, Coronado, Miramar, etc. or each of these installations. The definition of the installation to be studies is made by the authority directing the study. If the Commanding Officer of NAS, North Island orders the study the base is North Island. The missions of the NAS and all the tenant commands located on North Island are included in the study.

4. The Study Group

The study group is the collection of persons who will be responsible to the base commander or the study authorizing officer for the administering of the Seismic Risk Mitigation Study as defined herein. The makeup of the study group is of importance, since the decisions they will have to make may affect the ability of the base to function after an earthquake. The study group will require information on the possible missions of the base and its tenant commands. It needs authority to distribute questionnaires, to contact individual department heads and tenant commands concerning their missions and facilities. They will need access to Public Works records on building construction and modifications, the Phase I and II studies if completed, and other information such as base master plans, etc. A good deal of the information that is needed by the study group is within the domain of the Public Works Department or Center so the inclusion of an engineer either civilian or military is required. The inclusion of a person with access and specific knowledge of the operations and missions of the base and its tenant commands is recommended. The study group should not be overly large with a representative of every department and tenant command, but a small group of about four that can meet and work to perform this study. As will be seen the study will require a good deal of time and effort on the part of the study group. The forming of a committee to perform this study would only delay the completion and possibly erode the desired results by the inclusion of self-interests.

III. DETERMINATION OF MISSION ESSENTIAL FACILITIES

The determination of mission essential facilities must start with the missions of the base. A facility is not important unless a mission essential function must be performed in it. Keeping this facet in mind the basic steps in determining which facilities are mission essential are:

1. Determine the missions and mission elements of the base.
2. Translate the mission functions to facilities.
3. Determine the "uniqueness" of the facility.
4. Determine subordinate facilities to the essential facilities.
5. Obtain approval of the essential facilities listing.

The Seismic Risk Mitigation Study (hereafter refered to as the study) will require the involvement of many people beyond the study group. The basic translation of missions into facilities is performed using a survey distributed to department heads/tenant commands. The involvement of these people in the survey process and later discussions is a key to the success of the study.

A. DETERMINE THE MISSION FUNCTIONS OF THE BASE

Every Naval activity is assigned general and specific missions by their chain of command. The assigning of the mission can be in the form of instructions, contingency plans or other documents. In determining the mission functions of a base the study group must consider the activities performed by the base and all its tenant commands under the three possible mission scenarios: peacetime, contingency or wartime and disaster recovery operations.

Each of these scenarios are examined to ensure that an otherwise unimportant facility is not overlooked. An example might be a gymnasium that is used for emergency shelter during disaster recovery operations. The documents that identify the mission functions under the possible scenarios need to be researched by the study group. This is to ensure that all mission functions of the base/tenant commands are considered during the determination of mission essential facilities process.

B. TRANSLATE THE MISSION FUNCTIONS TO FACILITIES

Translating the mission functions into facilities is a procedure that should be done by the commands involved at the department head/tenant command level. The procedure for the translation of mission functions to facilities is a four part questionnaire/survey developed by NCEL and modified by the author. The questionnaire is designed to be filled out by the department head/ tenant command as that officer will be the most knowledgeable of the information requested by the survey. [Ref. 1]

1. Questionnaire Procedures

The procedure for filling out the questionnaire and for performing this translation are described below.
Survey forms and instructions along with a sample completed survey are contained in Appendix A.

Also contained in the questionnaire procedures are insights as to the reasons for the questions and the intended results of the questions.

a. Part 1A: Mission Statements

Instructions for Part 1A: Briefly write the general mission statement of the unit/department.

Additionally, include any special mission requirements not included in the general mission statement for peacetime, contingency or disaster recovery missions.

The intent of part one is to identify the mission functions performed by the unit/department/division being investigated.

b. Part 1B: Tactical/Strategic Mission Elements

Instructions for Part 1B: From the general and specific mission statements shown in part 1A, extract those elements that are of tactical/strategic significance. Include those elements that have direct significance to the military mission. Indicate in which readiness/alert condition the military element is performed. Do not include mission elements that are not of strategic or tactical military significance.

The readiness/alert conditions requirements are established in OPNAV Instruction C3500.29 series. The intent in Part 1B is for the user to differentiate between what is most important in their specific mission functions. The use of the readiness conditions gives the study group an indication of the user's importance of the function between peacetime and contingency operations.

c. Part 2: Functional Breakdown of Mission Elements

Instructions for Part 2: For each strategic/tactical element shown in Part 1B, provide a detailed breakdown of all tasks or functions that must be accomplished to perform the mission element. Be specific. Include all support service provided to your unit/department upon which you are dependent to accomplish the mission element even if it is not under your control. Show the element number from Part 1B in the space provided.

The intent here is to translate specific mission elements that may be written in unique acronyms into more general language. The study group will, most likely, not be familiar with all the acronyms used in the mission statements, Part 2 translates the general mission functions into more manageable pieces.

d. Part 3: Further Functional Breakdown of Mission Elements

Instructions for Part 3: For each of the functions or actions listed in Part 2, show all facilities and utilities required to accomplish the function. Include all support facilities and utilities even if they are not under your control. Note the functions shown are only those required to support strategic/tactical mission elements of direct military significance. Include all special requirements, such as electrical power, telephones, mechanical air conditioning for equipment, etc. Show the current building number or other identification where the function is performed.

In Part 3 the unit/department has evaluated their mission functions and translated them into specific facilities and utilities.

e. Part 4: List of Facilities Presently Occupied

Instructions for Part 4: List all buildings/facilities in which your unit/department occupies space and performs functions that are of strategic or tactical military significance. Include all direct support facilities over which you have control. Do not include buildings that are not of military significance. Show the function performed in the building. Indicate special requirements, such as backup electrical power. Indicate your opinion of the facility type as described below.

Indicate if the function can be relocated in an emergency, if so to where. Give a building number or description. Indicate if a back-up for this function exists on base, in the local area, on other federal installations in the area, if so where. Give an estimate of how long this function could be interrupted in an emergency, without impairing the mission function.

Part 4 is in part a reiteration of Part 3 but with much more information. The special requirements and information on the extent to which the facility could be relocated or interrupted or if the facility is duplicated are all required in the evaluation of the facility for "uniqueness". The facilities type used in Part 4 is an indication of the uniqueness of the facility, it is another indicator to the study group of the user's perception of how important his particular facilities are.

Descriptions of the facilities types are:

<u>FACILITY TYPE</u>

1 Critical structure containing materials that, if released into the atmosphere, could cause a catastrophe.

2 Facilities directly supporting the military strategic/tactical missions that must remain functional after an earthquake without significant interruption to prevent serious degradation of the military mission. Examples include: mission essential and primary communication or data-handling facilities, facilities involved in missile control, launch, tracking or other critical defense capabilities.

3 Facilities directly supporting the military strategic/tactical mission that can substain minor damage resulting in some limited period of inoperability but are repairable and can be returned to service. Also included are indirect support services supporting medical treatment, food preparation, fire fighting, utilities. Type 3 facilities generally house functions that are not relocatable and for which backup sources are not available.

4 Facilities important to indirect support facilities that are significant to maintaining direct support operations. Direct support facilities that have backup or are relocatable.

5 Indirect support facilities (shops, repair

facilities, storage facilities) that can tolerate disruption or can be relocated to other facilities or easily reconstituted.

From the initial survey the study group develops an initial listing of facilities by facility type. This listings is the first cut of the mission essential facilities. The study group must not take the facility type determination of the users as final, as this is the users opinion and the user has an inherent interest in the self-importance of his mission functions. Also the instructions may not have been understood. The listing derived from the questionnaires is a begining that is most useful to the study group.

2. <u>Determine the "Uniqueness" of the Facility</u>

From the completed surveys, the study group will have a listing of facilities that are currently being used to satisfy the missions of the base and its tenant commands. This section uses the information provided in Parts 3 and 4 of the survey along with additional information to determine the "uniqueness" of the facility. This section and the next section on determining subordinate functions are the most important in the determination of important facilities, are conducted concurrently and are revised and updated as information is gathered.

Uniqueness is comprised of three elements: the extent to which the facility can be: relocated, interrupted, and is duplicated. (relocatability, interruptability and duplication)

Relocatability is the ease of relocating the function to another location in the area, on or off base. Most any administrative function can be easily relocated where as a function requiring specialized, temperature controlled equipment can not. The easier the function is to be relocated and returned to operation after an earthquake the less unique the structure housing the mission function is. For example: the base commander is considered an important function, however if his office is destroyed he can easily relocate to any undamaged space that meets his needs of power, telephone, etc. This step is designed to highlight those mission functions that are generally limited to the facility where they are currently located. An example of a non-relocatable function is a communications center. The specialized equipment has certain power, temperature control and cabling requirements that are not generally repeated on base. The easier the function is to relocate the less unique the facility housing the function is.

Interruptability is a relative measure of how long the missions can be performed without this specific function element. How soon after an event is that mission function required. Arbitrary divisions of seconds, minutes, hours, days and weeks give the study group indications of the relative importance of the mission function. The longer the timeframe for need the more interruption the function can accommodate and hence the facility type can be lowered.

Duplication is the extent to which the function is duplicated within the area, on base or off. Duplication of services or functions may not seem very common but they can occur. Messing services are usually scattered throughout the base; gallies, clubs, and snack bars all could serve as messing areas if needed. At an air station, functions performed by one squadron are usually duplicated by others. All mission functions that are required need to be examined for duplicate facilities performing the same function. Duplication generally requires the same type of equipment at both sites.

Figure 3.1 shows the effect of the uniqueness considerations on the determination of facility types. As a facility becomes less unique, i.e. relocatable, interruptable or is duplicated, its category can be lowered. Facility type 2 is intended to be reserved for those facilities that must continue where they are with no break in service. Figure 3.1 is a generalized example, the actual facility determination must take into account the specific situation encountered.

With the possible changes in facility types due to the uniqueness considerations, the definitions for the different facility type categories as defined above are generally ignored. During and after the evaluation for "uniqueness", the facility types, except facility type 1, become an indicator of the relative importance of the facility.

The adjustment of the facility types during the evaluation of facility uniqueness is not so much a lessening of the importance of the mission function being performed in the facility, but a realization that the facility is not unique to the assets of the base.

"Uniqueness" is a relative function and a determination that will require the most documentation and justification for the decisions. The review by the base commander and others in the chain of command should probably focus on the "uniqueness" items. If a facility is reduced to type 3 because of the duplication of a facility nearby, the chain of command reviewer needs to be aware of this when reviewing the study. The reason is obvious, if the machine shop at base A says all their work can be done by the machine shop at base B and the machine shop at base A is reduced to a type 3 facility the same arguments can be used to reduce the machine shop at base B. The problem exists at the local level also. The study group needs to be aware of

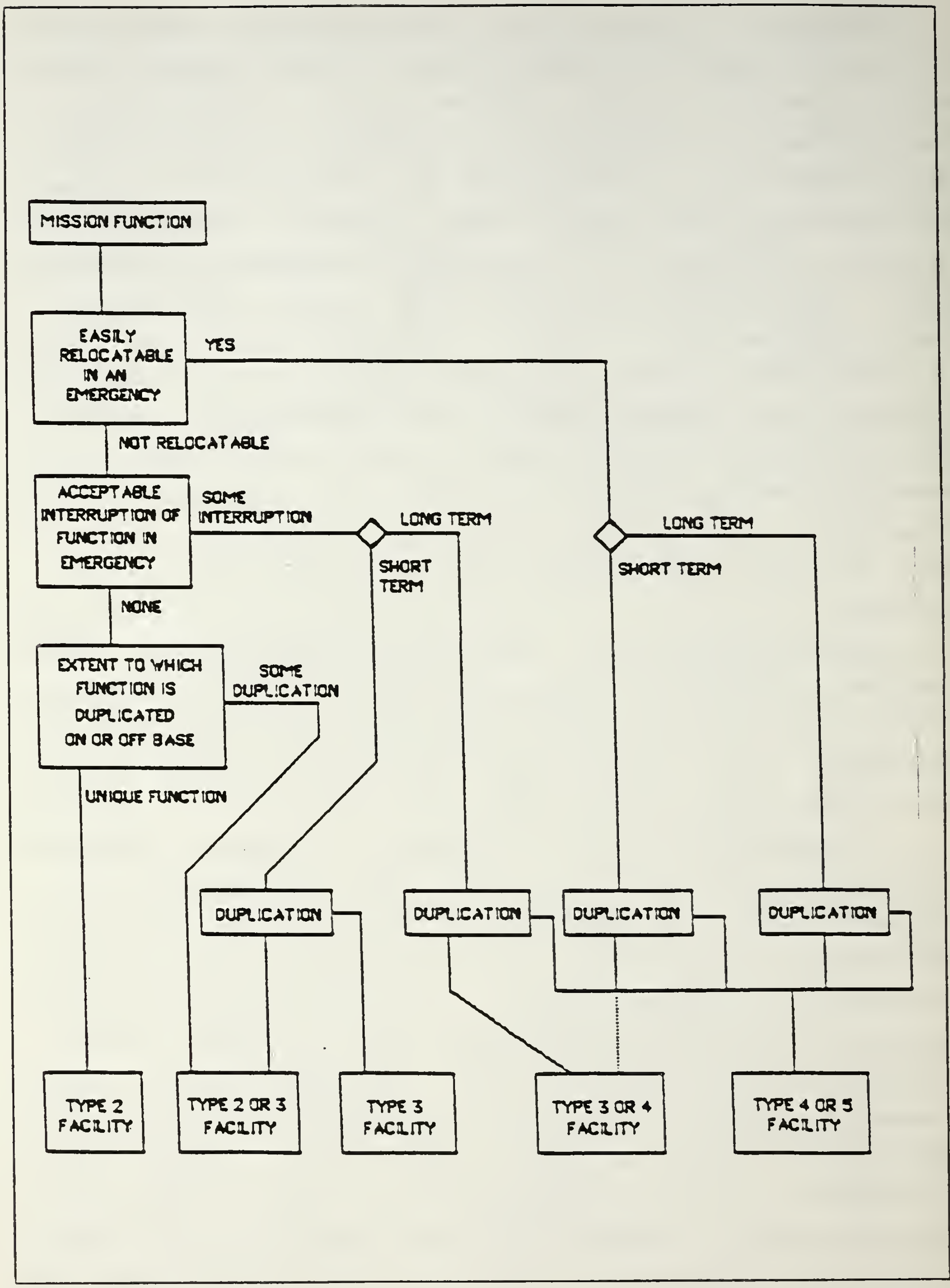


Figure 3.1 Uniqueness Considerations.

the possibility of reducing all similar type facilities because of duplication. Whenever duplication is assumed, the intended use of the duplicate facility must be highlighted in the study package. Duplication needs also to be considered in the expected post-disaster environment. Many functions would be temporarily stopped freeing up equipment for required repair or mission essential operations. The information on uniqueness and the information provided in the next section are essential parts required in the development of the Emergency Facilities Use Plan. Appendix D outlines the contents of the Emergency Facilities Use Plan. Using the messing example, a listing of all possible messing facilities (galleys, clubs, snack bars) is provided along with the characteristics and desirabilities of each. The collection and availability of this information for use in the event of an emergency may save valuable time in reestablishing the mission performance of the base.

An integral part of this section and the next are discussions with the facility user by the study group. The most important facility user is that department/tenant who is causing a facility to be classified type 2 or 3. There may be one room that is causing a facility to be classified as type 2. The study group's concern is with the function being performed in that room. How relocatable is the function, how much interruption is allowable; to what extent is that function duplicated. The study group will have information from the surveys, mission documents, Phase I and II studies, base master plans, damage estimates, etc. and can discuss the needs and thoughts of the facility user. These discussions will answer the questions on facility and function uniqueness and what subordinate functions are required to support the specific facility and function.

Thus far in the study no mention of possible damage has been made. In discussions with department heads/tenant commands expected damage must be looked at in isolation initially, as in the damage to a specific building. What will the department head do if his building is damaged? Then discussions on the impacts of the expected damage to the base in general as discussions progress. First, in the discussion a "what if" question in isolation is asked: What will you do if an earthquake destroys only your function? If the determination is made that the function is easily relocatable or duplicated questions need to be asked on how will the people, materials, etc. get to the new location. At this point the extent of damages can become generalized. If the function requires the movement of large trucks, will the trucks be able to move, given the anticipated damage along the route? Does the installation have sufficient trucks to perform the required movements to meet the mission demands? All aspects of the proposed actions need to be explored taking into account the anticipated damage.

3. <u>Determine Subordinate Functions to Mission Essential Facilities</u>

The survey provides the study group with information on the important facilities for the performance of a base's missions and a listing of special requirements to perform those missions. To more specifically define the special requirements a follow up survey was developed by NCEL for all type 2 and 3 facilities. These survey forms are included in Appendix A. Copies of survey forms 2 and 3 are sent to the units/departments who are causing a facility to be classified as facility types 2 and 3 respectivly. These surveys are intended to gather more information on the uniqueness of the function and the support functions required to sustain the function's operation. These surveys should be distributed and returned before specific interviews are conducted.

The study group armed with the results of the surveys and knowledge of the missions of the base, is now prepared to totally evaluate the base for the mission important facilities. Any adjustments to the facility type listings resulting from the results of the follow-up surveys need to be made. Next the study group conducts interviews with the units/departments whose functions are causing a facility to be classified type 2 or 3. These interviews are to examine the mission functions being performed therein, the utilities required to perform the functions, the interdependences from other units/departments required to perform the function, the interruptability, the duplicity or the relocatability of the function. Face to face discussions with the department head/unit representative can lead to innovative thinking and ideas not thought of when the surveys were filled out. This may cause the facility to be typed in another category or upgraded or reveal another facility that is required to ensure the function is performed. An example: if a function requires a specific telephone cable to perform its mission, the portions of the telephone system containing that cable now becomes as important as the function it is supporting. The building housing the telephone exchange may now become a type 2 or 3 facility. The discussions with the units/departments can reveal what their impressions of the support to them are and what their needs really are. The study group must act as a devil's advocate to try to lessen the facility type and as an advisor to the unit/department to upgrade the facility type. With the knowledge of the overall missions of the base, the relative importance of the facilities, the study group is in the unique position to determine the overall importance of the facility. The discussions with the user provides a forum for the expression of the users concerns and the possibility for some "what if" discussions. The study group may have information from their investigation of the base that need to be presented to the user. For example: if a portion of the base is subject to flooding by tsunamis the user who has a type 2 or 3 facility in a possible flooding zone must be made aware of this possibility. The user's plan for dealing with this possibility may reveal a new insight as to the importance of the facility or the increased importance of another facility. Previously mentioned was the possibility that a single room may cause an entire facility to be classified as type 2 or 3. During the discussions with the users the possibility of moving this function to another facility should be discussed and some of the problems associated with such a move aired.

Evaluating the facility for "uniqueness" and determining the subordinate facilities are the most important parts of the survey process. Without these two steps the mission essential facilities could have been named by the Commanding Officer (CO). A CO's list of mission essential facilities would be based on the CO's knowledge of the bases missions and the functions performed in the various buildings. What would most likely be missing from a list prepared by the CO is the dependence of that mission essential facility on another facility. If the communications center is dependent on a telephone cable to perform the mission, that cable is as important as the facility housing the communications center. If the telephone cable passes through switching gear in another building, that switching gear is as important as the communications center.

The final rank ordering of facilities by the study group is based on all the considerations outlined above.

The reasons why a facility is classified as it is need to be documented to aid in the review process. Again the reminder that the purpose of a facility is to house a mission function. If the function is easily relocated, the documentation should so state. If the function is duplicated, the documentation should state where the duplicate facilities are. This is the information the base commander and the chain of command reviewers need to have to approve the facility type listing and the overall plan. The end result of this section of the study is the listing of the most important base facilities and information required for the Emergency Facilities Use Plan.

The Emergency Facility Use Plan is a natural by-product of this study, each mission function is identified and facilities that could be used to satisfy the mission function identified. Recommended format and contents of the Emergency Facility Use Plan are contained in Appendix D.

4. Approval of the Mission Essential Facility List

The facility type listings need to be approved by the base Commanding Officer. The study group should prepare the facility type listings along with a brief explanation of the survey process. The study group, most likely, will know which facilities the Commanding Officer feels are mission essential and if these facilities are not in types 2 or 3 should highlight the reasons why the facility is typed lower. This is where the documentation plays an important role in defending the decisions made by the study group. However, the study group should be prepared to adjust the facility type listings based on the Commanding Officer's decisions. It is at this point where the facilities types 2 and 3 are labeled as "mission essential" and "very important" respectivly. Facility types 3 and 4 are labeled as "important" and "others" The use of word descriptions now are used to highlight the special importance of these facilities over other base facilities. With proper documentation there should be little adjustment by the commander.

With an approved facilities type listing, as direction is required for selecting facilities to be evaluated under the engineering and seismic studies the base is assured of having the studies performed on the facilities that are most important to them.

C. RECAPITULATION OF STEPS

1. Distribute the Tactical/Strategic Investigative Survey to Department Heads/Tenant Commands.

2. Examine the mission statements of the base and tenant commands.

3. Gather information on the earthquake potential, expected damage, etc. Examples include: Phase I and II studies, Base Master Plans, state or community disaster estimates.

4. Evaluate surveys, determine facilities types listings from user's estimates.

5. Distribute follow-up questionnaires to the department/unit who are causing a facility to be type 2 or 3.

6. Evaluate follow-up questionnaires, determine type 2 and 3 facilities based on follow-up questionnaires.

7. Conduct interviews to determine "uniqueness" of the facilities and subordinate facilities required.

8. Prepare final type 2 and 3 facilities listing with documentation for base commander's approval.

IV. PRIORITIZING PROJECT UPGRADES

The previous chapter outlined a procedure to classify the bases facilities into facility types. The question of how seismically safe those facilities are remains to be determined. Safety involves the hazards inherent in the facility structure, the hazards from the machinery and furnishings (nonstructural hazards) in the facility and the hazards from nature's effects, flooding, etc.

The evaluation phase contains two sections. The first concerns the gathering of information concerning the seismic threat and upgrading projects. The second section is concerned with evaluating the information to determine a rank ordering of the upgrading projects.

The output from this section are rank ordered lists of upgrading projects. These lists are differentiated by the different facility types. The intended use of the rank ordered listings is in the development of upgrading project funding submissions. The rank ordering process provides an indication as to the seismic upgrading benefit from the invested cost to upgrade the facility. Within the facility type determination is a facility importance concern. Based on the relative mission importance described by the facility types, facility type 1 projects should be funded before type 2 and so forth. It can be imagined that the projects developed may far exceed even a liberal estimate of funds available to correct the seismic hazards problem. In this light only facility types 1, 2 and possibly 3 should be evaluated at first. The effort required to determine the different costs is extensive and could be expensive. Limiting the evaluation to the first two or three facility types at the outset is recommended. In the event that there are only a few upgrading projects identified, facility types 4 and 5 could then be evaluated.

A. INFORMATION GATHERING

The results of the engineering and seismic studies will provide much of the information required for the rank ordering process described in this chapter. However, much additional information is required and is described below. Information required for other models presented may be in excess of that described below. When additional information is required methods for obtaining the information are outlined. The types of information that are required concern the facility replacement cost, upgrading costs, anticipated damage, etc. The sources of this information are varied and differ as to the reliability of the information they provide.

For the information collecting portion a worksheet has been developed. A copy of this worksheet, entitled the Individual Facility Worksheet is included in Appendix A. The various inputs to the Individual Facility Worksheet are be described below.

1. The Individual Facility Worksheet

a. Facility Number and Facility Type

The facility number and facility type are self explanatory.

b. Relocated From/To

The "Relocated From/To" line is used as an indicator. Previously mentioned was the consideration that a single mission function could cause a facility to be typed high. The relocation from/to line is used in two ways. The "relocated to" indicator is used if the mission function causing the facility to be typed as it is can be relocated. On the line the "to" is circled or underlined and the facility number of the facility proposed for the relocation of the mission function is indicated. Relocation is useful if there is one mission function causing an otherwise unimportant facility to be classified high or if the costs to seismically upgrade the facility occupied are quite high. Based on the knowledge and information the study group would possess at this time, a suitably relocation facility could be found. Relocation inplies lowering of the facility type. If a mission function is relocated, the facility is reevaluated to determine the new facility type. The study group would have all the necessary information required to determine the new facility type from the basic survey. Consideration must also be given to the overall effect of relocation. If a facility has collectively: a type 1 mission function and four type 2 functions, the benefits of relocating the type 1 facility may not be worthwhile because of the type 2 facilities also occupying the facility. The "relocated from" indicates the mission function is being considered for relocation to the facility represented by the worksheet. The "from" is circled or underlined and the facility number of the mission function being relocated is placed on the line. For "relocated from" facilities a worksheet is prepared and the costs associated with relocating the mission function are prepared and entered. The elements of relocation costs are outlined below. The "relocated from" facility worksheet is attached to the "relocated to" worksheet to highlight the potential facility type and the relationship to the relocated function, if the mission function is relocated.

c. Damage Estimates

The damage estimates are required for the determination of the costs if an earthquake happens. The damage estimates are an essential part of the Phase I studies. The Phase I studies provide damage estimates in percent damage for three different Peak Ground Acceleration (PGA) "g" force levels or return times. On the worksheet damage estimates for the three Phase I study levels or return times are entered. Level refers to the return time or PGA "g" level, percent is the percent damage estimated, and source is the Phase I or other source.

The next line on Probable Damage is the probability of occurrence of the different seismic events times the percent damage estimates for those events. The method for calculating the probable damage is presented in the rank ordering technique section.

d. Replacement Costs

The next section concerns the replacement cost of the facility. The replacement cost includes both the structural replacement cost and the cost to replace the furnishings, contents, or systems serving the facility. The structural replacement cost of specific facilities is contained in the "Detailed Inventory of Naval Shore Facilities" NAVFAC P-164 distributed to each Shore Facility by the Naval Facilities Engineering Command. This document contains the theoretical replacement cost of existing facilities based on the actual purchase cost and a year cost correction factor. The structural replacement cost provided is of good value and is sufficient for use in the evaluation process.

The contents and systems replacement costs are as important, and perhaps more so, than the structural replacement costs. What makes a facility important is the mission function being performed in the facility. Generally, for a type 2 facility there is a piece of equipment that is required to perform the mission. The computers supporting the Communications Center is an example. The cost to replace the mission required equipment may be more than the cost to replace the building it is located in. The structural and contents replacement costs together form an important base in evaluating the upgrading projects. The results of the evaluation process without these contents costs is in effect, worthless.

Unfortunately, there is no one source of contents replacement costs as there is for the structural replacement costs. Content items, furnishings or equipment, originally costing over $1,000 and $3,000 are recorded as plant property Classes III or IV as appropriate. The plant property records are maintained by the Authorization Accounting Activity serving the base. Memorandum records are usually maintained by the base comptroller. Plant property class III is equipment, other than Industrial Plant Equipment, that has a useful life of over two years and a cost of over $1,000. Class III property does not form an integral part of a building or another piece of equipment. Examples include:computers, typewriters, etc. Class IV property is Industrial Plant Equipment, costing over $3,000. Class IV is often refered to as equipment that makes equipment. Machine tools, lathes, etc. are examples of Industrial Plant Equipment. The Defense Industrial Plant Equipment Center monitors and manages the Industrial Plant Equipment. Specific information on Class III and IV Plant Property definitions, accounting, etc. are contained in Reference 22.

Generally, the plant property records are not filed by facility number but are filed by responsible department. The translation of the equipment costs to specific facilities, as is necessary for determining nonstructural replacement costs, will be a time consuming job. Assistance from the departments responsible for the equipment in determining the location of the equipment will greatly reduce the work of the study group.

The plant property records reflect the purchase cost and must be adjusted to reflect the replacement cost. Replacement costs for much equipment can be found through the supply department, or the user may be able to provide an estimate. Replacement costs provided by the supply department are generally of a higher reliability than estimates provided by the user. If no estimates of the replacement cost can be provided, the original purchase cost as shown on the plant property records can be used.

Consideration must be given to the level of detail that goes into the determining the contents replacement costs. The decision to include all equipment in a facility or only mission required equipment is an important consideration. This determination is left up to the study group as local conditions vary. The effort involved in separating the mission required equipment from the other equipment may be as much as the effort involved in including all equipment. Generally, the more information available the better. In either event, the contents replacement costs must be determined consistently for all facilities on a base. Different criteria for assigning contents replacement costs may affect the evaluation process.

Contents replacement costs provided by the plant property records contain only the high cost items. Costs of equipment costing under $1,000 can be estimated by counting the number of desks, typewriters, mission required equipment, etc. and applying their replacement costs.

Depending on the mission function these costs may not be trivial so it is important that this step be carried out. Warehouses and inventories are special cases, an average of the inventory usually carried is adequate to be used as a contents replacement cost.

So for a multi-use building there can be replacement costs from computers, inventories, desks, machine shops, etc. The total of all these contents or furnishings or equipment replacement costs is the total contents replacement cost of that facility. There are several lines to be used to identify some of the high cost items if desired.

The total replacement cost (structural and contents) is determined for each facility and is entered on the worksheet.

The Total Damage line is the Total Replacement Cost times the Probable Damage estimate of the facility. The method for determining the Probable Damage estimate will be developed in the section on Rank Ordering Technique.

e. Upgrading Costs

The next cost required for the worksheet is the upgrading cost. The upgrading costs are comprised of three types, structural, nonstructural and other upgrading costs. The Phase II studies provide the structural and nonstructural upgrading costs. If the Phase II study has not been performed at the base the listings of facilities by facility types should be used to direct the Phase II investigations. Facilities typed as 1, 2 and 3 should be evaluated under the "Mission Essential Criteria" option of the Phase II investigation. If the facility was not evaluated under a Phase II study these costs can be gathered from other sources. Structural and nonstructural upgrading costs for facilities not evaluated by a Phase II study can be obtained by commissioning a Phase II study through the Engineering Field Division. The Public Works department or center may be capable of performing the structural study. The method chosen will depend on the complexity of the facility and the funding available to conduct the study. For type 1 and 2 facilities a Phase II type study should be performed. For type 3 to 5 facilities a less reliable estimate can be used. Consistency within each facility type is again recommended.

Nonstructural upgrading costs can be estimated by the study group or by Public Works. References 23 and 24 present techniques for evaluating a facility for nonstructural hazards. Estimates of the cost to reduce these hazards can be provided by the public works department or center.

The other upgrading costs are the costs to reduce the nonfacility related seismic hazards. These can be the hazards from flooding, tsunamis, earthslides, etc. Each of these hazards need to be individually examined and costs to reduce these hazards assigned. If, for example, a facility is subject to flooding perhaps the best alternative would be to relocate the function. If an additional retaining wall would reduce the damage from flooding the cost to construct the retaining wall would be included in the total cost to upgrade the facility.

f. Relocation Costs

The relocation costs include the cost of moving the function, the cost to rehabilitate the new location (except seismically), the cost of the mission function equipment to be relocated and any costs involved with discontinuing the function to allow the move. The costs to seismically upgrade the receipt facility are not considered in the relocation cost. As the seismic upgrading cost are already included in the upgrading cost for the proposed relocation facility prepared under a Phase II study. As an example, if a computer operation was to be relocated the relocation costs would include: The replacement cost of the equipment, files, desks, etc. required to perform the mission function being relocated, and the cost associated with moving this equipment. Also included are the costs to prepare the receipt facility for the function: increased electrical circuits, air conditioning, office spaces, computer flooring, etc. anything that is required to allow the function to operate. Lastly are the costs associated with the discontinuance of operations during the actual moving period. In the example, if time on another computer system is required to perform the mission tasks or a specialist is required to recertify the equipment after the move, these costs should be included as relocation costs. If in the example, it is decided to purchase a new computer to put into the new spaces rather than move the old computer, the inclusion of the cost of a the new computer as a relocation cost is left up to the determination of the study group. The replacement costs of the mission function equipment is necessary to reflect the increased replacement value of the facility, if the function is relocated.

The information on the completed worksheets are useful in the development of the base's Seismic Damage Potential Map. The definition of the Seismic Damage Potential Map and the procedures for developing one are described in Appendix E.

When the "Relocated From/To" indicator is used the process indicates the Individual Facility Worksheet should be placed with the worksheet of the facility from which the mission function is being relocated. Additional replacement and relocation costs are added to the base costs of the facility rendering the worksheet in error for evaluation of the basic facility if the relocation is not accomplished. Therefore, the use of multiple Individual Facility Worksheets for a single facility is recommended. For the evaluation of a possible relocation facility within its original facility type the replacement and upgrading costs of the facility without any relocation costs are used. For the evaluation as a relocation site the base (replacement and upgrading) costs and the additional (upgrading) costs are indicated. If the determination is made to relocate the duplicate worksheet can be removed. If more than one relocation is suggested for a facility the individual additional relocation related costs should be on one worksheet and the combined relocation related costs should be on another worksheet.

The Phase I studies may not evaluate every building on a base. Often a single facility is evaluated and the results are assumed to be the same for all similar facilities. For example, if a base has seven barracks buildings built to the same design at the same time, the results from the Phase I study can be applied to all the seven buildings. Depending on the circumstances the Phase II engineering studies may be used in the same manner.

With all the costs gathered and the worksheet completed the evaluation or rank ordering process can begin.

B. RANK ORDERING MODEL

The technique for rank ordering the upgrading projects is through the use of a simple model that uses the information available from the Individual Facility Worksheets and the Phase I study. The model is as follows:

$$R = \frac{\text{Change in Damage}}{\text{Upgrading Costs}}$$

Where:

R = the relative ranking of the facilities upgrading project.

Change in Damage = The dollar estimate of the expected damage to the facility before upgrading less the dollar estimate of the expected damage to the facility after upgrading (Damage w/o Upgrading - Damage w/ Upgrading).

Upgrading Costs = The dollar estimate to upgrade the facility from the Individual Facility Worksheet.

The projects are ranked by the value of R.

The assumptions involved with this model are:

1. It is to be used as a tool to aid decision makers, and not as an absolute determinant.
2. The level and reliability of the data used is relatively constant across facility types.

1. Change in Damage

The numerator, Change in Damage, is the measure of the seismic hazards reduction the upgrading project would provide. The expected damage is based on the probability of occurrence of an earthquake. Inherent to the Phase I study is a table of the probability of occurrence of Peak Ground Acceleration (PGA). This table is a product of the Site Seismicity Study portion of the Phase I study. Table VII is the table from the NAS, Moffett Field Site Seismicity Study [Ref. 19]. These tables are determined by automated means based on the location of the base to known earthquake faults and other geologic and seismic information.

To utilize the table it must be converted into a graph of the cumulative and individual probabilities versus the PGA. Figure 4.1 is such a graph. The data on the cumulative probability distribution line is simply the data from Table VII. The data on the individual probability distribution line is derived from the information in Table VII With the graph and the damage estimates provided by the Phase I study the expected damage can be computed.

TABLE VI

Probabilities of Exceedance of Peak Ground Acceleration

PGA (g's)	P Exceedance in 50 years
0.00	1.0000
0.05	0.9990
0.10	0.9563
0.15	0.7698
0.20	0.5803
0.25	0.4452
0.30	0.3383
0.35	0.2571
0.40	0.1979
0.45	0.1518
0.50	0.1166
0.55	0.0901
0.60	0.0706
0.65	0.0542
0.70	0.0405
0.75	0.0310
0.80	0.0241
0.85	0.0179
0.90	0.0136
0.95	0.0101
1.00	0.0071

a. Damage Without Upgrade

The expected damage to the facility without any upgrade (Damage w/o Upgrade) is determined by computing the total probability of damage for the facility being

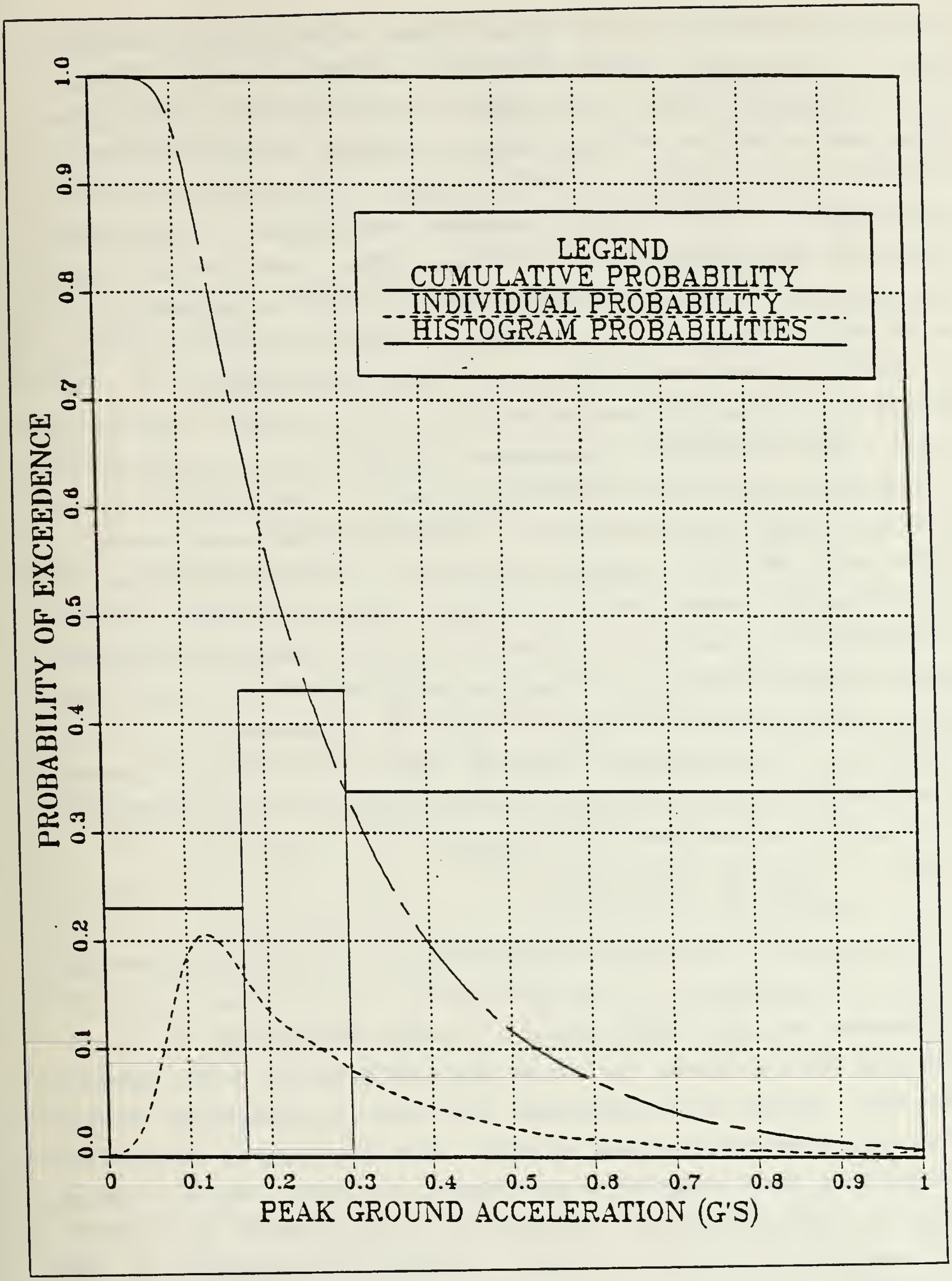


Figure 4.1 Probability of Exceedance.

evaluate . The Phase I study provides a damage estimate for three PGA levels, corresponding to three return times. Using the probability graph and the PGA levels a histogram of the probability of occurrence of those three PGA levels is constructed. The probabilities of occurrence of the various PGA's are divided into three categories. The three categories are computed as follows: The first category is the PGA from 0 to the mid-point of the PGA's associated with the 50 and 100 year return times. The second category is the PGA's from the mid-point just determined to the mid-point of the PGA associated with the 100 and 225 year return times. The final category is from the PGA associated with the mid-point just determined to 1. The probabilities associated with the occurrence of peak ground accelerations within each of the three categories is determined from the site seismicity study probabilities. The total probability of damage is found by multiplying the combined percent damage from the Phase I study for the PGA at the center of the category times the probability of occurrence of that category. The Damage w/o Upgrade is the total replacement cost times the total probability of damage just calculated. An illustrative example is included.

b. Damage With Upgrade

The expected damage with or after upgrading (Damage w/ Upgrading) is again based on the probabilities of occurrence of the PGA levels. The upgrading projects developed by the Phase II study are designed to a PGA level. This PGA level is determined by the Engineering Field Division administering the study. For facilities evaluated as "Mission Essential" by a Phase II study the upgrading design is to allow the building to remain functional after the design earthquake. The design earthquake is an earthquake up to the PGA specified. For this model the assumption is made that the damage up to and including the design PGA is 0. Damage above the design PGA is the basis of the Damage w/ Upgrade. Using the graph developed from the probability of occurrence the cumulative probability of occurrence above the design PGA is determined. This probability of occurrence is used as the percent damage for Damage w/ Upgrade. The use of this probability as the percent damage implies a 100% damage estimate. The use of the 100% damage estimate is appropriate for two reasons. First, an earthquake above the PGA of the upgrading design, most likely, result in loss of the mission function, even if the facility is not totally destroyed. For facility types 1, 2 and 3 the study is more concerned with the continuance of the mission function that the damage to the facility housing the function. Secondly, the use of 100% damage is the most conservative estimate. Use of this conservative estimate will lower the calculated R. As long as the 100% damage above the design PGA is applied consistently for all facilities, the effect of this assumption is minimized. The Damage w/ Upgrade is the percent damage times the new replacement cost of the facility. The new replacement cost is the replacement cost from the Individual Facility Worksheet plus the cost of the upgrading project. The increase in replacement cost is necessary to reflect the additional investment in the facility due to the upgrading project.

Due to the limitations of the Rapid Analysis technique used in the Phase I studies, some facilities are not studied or are represented by other facilities. These non-studied facilities are usually unique in function or design. Water towers, large arch hangers and utilities systems are examples. The percent damage estimates for these facilities should be determined by an engineering study. The Phase II study requirement should include an estimate of damage at the three PGA levels used in the Phase I study. If the Phase II study has been completed an engineering study should be conducted for all type 1 and 2 facilities, as a minimum, to determine these damage estimates. The engineering study can be such that it establishes a damage percent for the three PGA levels or that it provides a word picture of the damage at each PGA level. If the word picture option is chosen, Table VI is then consulted to determine the percent damage from the word picture of the expected damage.

2. <u>Cost of Upgrade</u>

The denominator, Cost of Upgrade, is the cost of the upgrading project developed by the Phase II study.

3. <u>Example Calculations</u>

An illustrative example: Appendix B contains the Phase I and II reports for Building 144 at NAS, Moffett Field. Using the information in the Appendix and the probabilities from Table VII and Figure 4.1 the relative rank ordering (R) for building 144 will be determined.

a. Damage w/o Upgrade

Probability of Occurance-NAS, Moffett Field was evaluated at PGA levels of 0.09, 0.25 and 0.34g corresponding to 50, 100 and 225 year return times. The categories for the probability histogram are 0 to 0.17, 0.17 to 0.30 and 0.30 to 1. The probabilities for these categories are 0.2302, 0.4315 and 0.3383 respectively.

Combined Damage Estimate-From the Phase I evaluation of Building 144 the combined damage estimate is 28.1% for 0.09g PGA, 66.7% for 0.25g and 66.7% for 0.34g.

Replacement Cost-$8,198,000 ($3,198,000 structural replacement cost and an assumed contents/nonstructural replacement cost of $5,000,000)

TABLE VII

Word Picture Damage Estimates

Description	Structural Damage	Nonstructural Damage	Percent Damage
No damage	none	none	<0.1
Minor nonstructural damage-a few walls and partitions cracked, incidental mechanical and electrical damage.	none	minor	0.2
Localized nonstructural damage-more extensive cracking (but still not wide-spread); possible damage to elevators and/or other mechanical/electrical components.	none	localized	0.6
Widespread nonstructural damage-possibly a few beams and columns cracked, although not noticeable.	not noticeable	widespread	2
Minor structural damage-obvious cracking or yielding in a few structural members; substantial nonstructural damage with widespread cracking.	minor	substantial	5
Moderate structural damage-cracking and yielding in a number of members; substantial nonstructural damage.	moderate	substantial	10
Substantial structural damage requiring repair or replacement of some structural members; associated extensive nonstructural damage.	substantial	extensive	15
Major structural damage requiring repair or replacement of many structural members; associated nonstructural damage requiring repairs to major portions of interior; building vacated during repairs.	major	near total	30
Building condemned.	not repairable	total	70
Collapse	collapse	total	>70

Probable Damage-Probability of PGA times the Damage at that PGA. 0.2302 X 0.281 + 0.4315 X 0.667 + 0.3383 X 0.667 = 0.578 or about 58% damage to the facility and contents without any upgrading.

Damage w/o Upgrading-$4,738,444 (0.578 X $8,198,000)

b. Damage w/ Upgrade

Probability of Occurance-The Phase II design PGA for NAS, Moffett Field is 0.34g PGA. From Figure 4.1 the probability of occurrence above 0.34g PGA is about 0.25.

Combined Damage Estimate-assumed to be 100%

Replacement Cost-$10,073,000 ($8,198,000 total replacement cost $1,875,000 upgrading project cost)

Probable Damage-25% (0.25 X 1.00)

Damage w/ Upgrade-$2,518,250 (0.25 X $10,073,000)

c. Cost to Upgrade

Upgrading Cost-$1,875,000 from the Phase II study.

d. Relative Rank Ordering

$$R = \frac{\text{Damage w/o Upgrade less Damage w/ Upgrade}}{\text{Cost of Upgrade}}$$

$$R = \frac{\$4,738,444 - \$2,518,250}{\$1,875,000}$$

$$R = \frac{\$2,220,194}{\$1,875,000}$$

for a R = 1.2

V. ALTERNATIVE RANK ORDERING TECHNIQUES

Two other rank ordering techniques will be examined here. Their background, strengths and weaknesses will be discussed. The two methods are: (1) Seismic Risk Mitigation Model of the Navy Earthquake Risk Reduction Panel; and (2) the Available Funding model.

A. SEISMIC RISK MITIGATION MODEL

The Navy Earthquake Risk Reduction Panel outlined the following model in their report on Seismic Hazards at U.S. Navy Installations. Their model will be explained in terms of the methodology outlined above. [Ref. 21]

Their model assumes that the facilities being evaluated by the model are (1) identified as having a relatively high risk from the Phase I study and (2) of relatively high importance in achieving the mission of the base. The two assumptions are met by evaluating the facility types 1 through 3 and by not evaluating facilities with low Phase I damage estimates. The panel addresses two caveats for their model. First, the model is intended to be a tool to aid decision makers, not a substitute for them. Second, the information required for the model is not necessarily easy to obtain, but is essential to the model.

In the basic model the value of upgrading a particular facility depends on four items:

1. The relative importance of the facility for performing the mission.
2. The probability of earthquakes affecting the usefulness of the facility.

3. The damage caused to the facility by an earthquake if the facility is upgraded.

4. The damage caused to the facility by an earthquake if the facility is not upgraded.

The relative value of upgrading facility "i", which is written as v(i), is:

$$v(i) = V_i \sum_m P_i(m)[d_0(i,m) - d_1(i,m)], \text{ all } i$$

where

V_i = the relative importance (i.e. value of facility "i" to performing the mission.

$P_i(m)$ = the probability of an earthquake of Modified Mercalli magnitude "m" over the expected lifetime of facility "i"

$d_0(i,m)$ = the percent damage (meaning percent loss of usefulness for performing the mission) to facility "i" caused by a magnitude "m" earthquake if there is no upgrade of the facility.

$d_1(i,m)$ = the percent damage to facility "i" caused by a magnitude "m" earthquake if the facility is upgraded.

The term $[d_0(i,m) - d_1(i,m)]$ indicates the percent reduction in damage to facility "i" caused by an earthquake of magnitude "m" if the facility is upgraded relative to if the facility is not upgraded. To use this model, it is necessary to determine V_i, $P_i(m)$, $d_0(i,m)$, $d_1(i,m)$ for all relevant facilities "i" and magnitudes "m" at a given base.

The V_i represents value judgments on the value of the facility "i". The methodology for determining the facility types will lessen the judgemental portion of this term. As can be seen the greater the value of V_i the greater the relative value of upgrading (v(i)) the facility. To maintain consistency with the importance of the facility types previously developed, facility type 1 should have

V_i values in the 90-100 range; facility type 2:80-89; and facility type 3: 50-79. If facility types 4 and 5 are evaluated their V_i Value should be less than 50. Assigning separate V_i values for each facility within a facility type is acceptable.

To determine $P_i(m)$ requires professional judgements from individuals knowledgeable about earthquakes and their affects. $P_i(m)$ can be calculated from a Poisson model of earthquake occurance for the base location. The probability of a magnitude "m" earthquake per year for each magnitude "m" could be determined. From the Poisson model and the remaining lifetime of the facility "i" the calculation of $P_i(m)$ is made. Note $P_i(0)$ would be the probability of no earthquake affecting facility "i" during its lifetime.

The damage estimates $d_0(i,m)$ and $d_1(i,m)$ would depend on professional judgments of two types. One type would concern the impairment of facility "i" when subject to an earthquake of magnitude "m" under upgraded conditions and if not upgraded. Estimates for $d_0(i,m)$ would be determined by experts in the field. The information gathered thus far has not provided the information required to determine $d_0(i,m)$ and $d_1(i,m)$.

After the information necessary is obtained and processed using the model formula, the result is a set of numbers v(1), v(2), etc. corresponding to the facilities evaluated. If v(1) is greater than v(2), then the relative value of upgrading facility 1 is greater than the relative value of upgrading facility 2. However this alone does not mean that it is more effective to upgrade facility 1. To account for the cost in upgrading the facilities the v(i) is divided by the cost to upgrade facility "i" [$(i)] to determine the relative effectiveness E_i.

$$E_i = \frac{v(i)}{\$(i)}$$

The larger the effectiveness E_i, the more cost effective it would be to upgrade facility "i". The rank ordering would be by E_i.

The basic model of the Panel has only been expressed. Variations to this model include considerations for costs of fatalities and reconstruction costs and a model that addresses different levels of upgrading. The models proposed by the Panel are presented in Appendix C.

The major drawback with the Earthquake Risk Reduction Panel Model and its variations is the effort required to evaluate the facilities. The determination of $P_i(m)$, $d_0(i,m)$ and $d_1(i,m)$ all require information not provided by the Phase I or II studies.

B. AVAILABLE FUNDING RANK ORDERING

The dollar estimates of the upgrading projects developed to reduce the seismic hazards will naturally vary. Projects that simply reduce nonstructural hazards in a newer facility may be relatively inexpensive. Projects requiring massive structural changes may be in the multi-million dollar range. Funding for the upgrading projects follow the requirements of funding other construction or repair projects. The different funding level categories are:

For Construction/Alterations:

Up to $25,000	Local Approval
From $25,000 to $200,000	Major Claimant
Greater than $200,000	Military Construction

For Repair:

Up to $75,000	Local Approval
From $75,000 to $3 million	Major Claimant
From $3 to 5 million	Secretary of the Navy
Over $5 million	Military Construction

[Ref. 25]

Naturally as the cost increases the competition for the funds becomes tougher. Evaluation of the upgrading projects developed by the different funding categories is now considered. The upgrading projects should be divided into the different funding categories by their estimated cost. The relative rank ordering developed by one of the methods previously described, should be retained such that all facility type 1 projects are listed before type 2 etc. Those projects within the Commanding Officers approval authority should be submitted for local funding. Possibly some of these projects could be accomplished by the Public Works workforce. The projects in the other funding categories should be considered for submission in those categories. The specific methods for these submissions vary, however, the Phase II study does provide a DD Form 1391 that can be used for project submission where required.

By considering the funding categories a type 2 facility may be seismically upgraded using local funds before a type 1 facility that requires major claimant funding is upgraded. The realities of competition for funds are such that deserving projects may never get funded. If the use of local funds can reduce some seismic hazards it should be done. The relocation option can use local funding authority to relocate a mission function from a facility with high expected damage to a facility with lower expected damage. Even without specific seismic upgrading relocation could improve the chance of the mission function remaining operational following an earthquake.

The author does not anticipate special funding to specifically reduce the seismic hazards within the Navy. The Phase II studies will provide the Navy with an estimate of their seismic vulnerability however the dollar figure to reduce the seismic hazard is far beyond what can be expected or requested of Congress. Certain facilities may be so important to the Navy that specific projects for seismic upgrading will be pursued. Such an example is the extensive seismic upgrading at the Naval Hospital at Oak Knoll, Oakland, California. The cost of this project is $29 million and is essentially a project to reduce seismic hazards [Ref. 26]. Without specific funding for seismic hazards reduction, seismic upgrading projects will either compete for funding as specific seismic upgrading projects or as a portion of the costs associated with other renovation/upgrading projects.

VI. CONCLUSIONS AND RECOMMENDATIONS

The threat of damage from earthquakes to Naval facilities is present. The vulnerability of a base and the missions performed on that base is the focus of several engineering and seismic studies. Directing the efforts of these engineering and seismic studies to best suit the needs of the base is the focus of this thesis. The concern is not so much with the survivability of the facility but the continued operation of the mission being performed in the facility. A procedure is outlined that evaluates the missions of the base and determines the facilities that are required to support those missions. The facilities are examined for their "uniqueness" to determine if the mission being performed in the facility can be moved after an earthquake. Further evaluation of the facilities determines the facilities that are required to support those "mission essential" facilities. The process is intended to provide a listing of the facilities that must be seismically protected because of the important mission function being performed in the facility. The facilities listings are used to direct the efforts of the engineering and seismic studies to evaluate the facilities that are most important to the performance of the bases missions.

Several methods are presented to evaluate the results of the engineering and seismic studies. These methods result in a rank ordering listing of the seismic upgrading projects developed by the engineering and seismic studies. The rank order listing is intended to be used in the bases decision process to determine which projects should be submitted for funding.

Two important by-products of the processes described would be an Emergency Facilities Use Plan and a Seismic Damage Potential Map. The Emergency Facilities Use Plan is derived from the information gathered during the evaluation of the bases missions and the determination of the facilities required to support those missions. The Emergency Facilities Use Plan is a central document that would outline the capabilities of the bases facilities in terms of what mission functions can be performed there, and conversly, what facilities can support certain missions. Appendix D outlines what constitutes an Emergency Facility Use Plan. A Seismic Damage Potential Map is another by-product of the process described in this thesis. Using the information provided by the engineering and seismic studies this map can be developed. A Seismic Damage Potential Map will show the seismic vulnerability of a base. Appendix E outlines the contents of a Seismic Damage Potential Map.

Recommendations for further research are:

1. The methodology as described has not been fully evaluated under a field test. A study using the methodology as described should be tested at a Naval base and recommendations on improving the process based on the findings should be published.
2. Without a full evaluation of the process in a field test portions of the methodology described could be used where the engineering and seismic studies have already been performed. The rank ordering process has application even if the determination of the "mission essential" facilities has not been made. Using the process described to evaluate the results of the engineering and seismic studies should result in upgrading project submissions that return the most benefit to the base for the dollars invested.

3. Portions of the methodology have applications outside the seismic hazards arena. The section on determining the mission essential facilities may have applications in evaluating facilities for priority of repair in a war damage environment. The application of the process for determining the mission essential facilities should be evaluated for use in this area.

APPENDIX A

SURVEY SAMPLES AND FORMS

Contents

INSTRUCTIONS FOR TACTICAL/STRATEGIC INVESTIGATION SURVEY

Part 1A: Write the general mission statement of the unit/department. Additionally include any special mission requirements not included in the general mission statement for peacetime, contingency or disaster recovery missions.

Part 1B: From the general and specific mission statements shown in Part 1A extract those elements that are of tactical/strategic significance. Include those elements that have direct significance to the military mission. Indicate in which readiness/alert condition the military element is performed. Do not include mission elements that are not of strategic or tactical military significance.

Part 2: For each strategic/tactical element shown in Part 1B, provide a detailed breakdown of all functions that must be accomplished to perform the mission element. Be specific. Include all support service provided to your unit/department upon which you are dependent to accomplish the mission element even if it is not under your control. Show the element number from Part 1B in the space provided.

Part 3: For each of the functions or actions listed in Part 2, show all facilities and utilities required to accomplish the function. Include all facilities and utilities even if they are not under your control. Note the functions shown are only those required to support strategic/tactical mission elements of direct military significance. Include all special requirements, such as electrical power, telephones, mechanical air conditioning for equipment, etc. Show the current building number or other identification where the function is performed.

Part 4: List all buildings/facilities in which your unit/department occupies space and performs functions that are of strategic or tactical military significance. Include all direct support facilities over which you have control. Do not include buildings that are not of military significance. Show the function performed in the building. Indicate special requirements, such as backup electrical power. Indicate your opinion of the facility type as described below. Indicate if the function can be relocated in an emergency, if so to where, give a building number or description. Indicate if a back-up for this function exists on base, in the local area, on other federal installations in the area, if so where. Give an estimate of how long this function could be done without in an emergency, without impairing the mission function.

FACIL[illegible]Y TYPE

1 [illegible]itical structure containing materials that, if [illegible]eleased into the atmosphere, could cause a catastrophe.

2 Facilities directly supporting the military strategic/tactical missions that must remain functional after an earthquake without significant interruption to prevent serious degradation of the military mission. Examples include: mission essential and primary communication or data-handling facilities, facilities involved in missile control, launch, tracking or other critical defense capabilities.

3 Facilities directly supporting the military strategic/tactical mission that can substain minor damage resulting in some limited period of inoperability but are repairable and can be returned to service. Also included are indirect support services supporting medical treatment, food preparation, firefighting, utilities. Type 3 facilities generally house functions that are not relocatable and for which backup sources are not available.

4 Facilities important to indirect support facilities that are significant to maintaining direct support operations. Direct support facilities that have backup or are relocatable.

5 Indirect support facilities (shops, repair facilities, storage facilities) that can tolerate disruption or can be relocated to other facilities or easily reconstituted.

For additional information contact:

Return completed survey to:

Classification UNCLASSIFIED

TACTICAL/STRATEGIC FACILITIES

INVESTIGATION SURVEY

SAMPLE

Organization NAS XYZ AIMD

Contact Mr. Smith

Phone A/V XXX-XXXX

Address P.O. Box xxx

NAS XYZ, CA XXXXX

CLASSIFICATION UNCLASSIFIED PART 1

ORGANIZATION NAS XYZ AIMD

A. GENERAL MISSION STATEMENT

INSTRUCTIONS: *Write general mission statement of unit. Include any special mission requirements not included in the general mission statement for peacetime, contingency or disaster recovery missions.* Performs intermediate aircraft maintenance in support of station and fleet aircraft and on associated equipment. Provides prepositioned maintenance support equipment and organizational maintenance facilities for tenant activities.

B. TACTICAL/STRATEGIC MISSION ELEMENTS

INSTRUCTIONS: *Write Tactical/Strategic mission elements in detail. Relate to readiness condition by placing check in box if performed in that condition. Do not include nonstrategic elements of mission.*

	TACTICAL/STRATEGIC MISSION ELEMENT	READINESS CONDITION				
NUMBER	Description	5	4	3	2	1
1	Provide Level 2 & 3 Aircraft Component Repair	X	X	X	X	X
2	Provide Level 1, 2 & 3 Aircraft Support Equipment Repair	X	X	X	X	X
	--SAMPLE--					

Classification UNCLAS PART 2.

FUNCTIONAL BREAKDOWN OF TACTICAL/STRATEGIC MISSION ELEMENTS

Instructions: *Provide detailed breakdown of strategic mission elements in Part 1B in terms of specific functions that must be accomplished by your unit. Include service support to your unit essential to accomplish mission.*

SPECIFIC FUNCTION		Element No. From Part 1B
No.	Action	
1	Reapir Aircraft Avionics WRA's	1
2	Repair Aircraft Structural/Hydraulic/Wheel Assemolies	1
3	Repair/Overhaul Aircraft T-56 Power Plants	1
4	Repair/Certify Aviator Life Support Equipment	1
5	Repair/Inspect Aircraft Armament Equipment	1
6	Maintain/Repair Test Equipment	2
7	Issue/Repair/Overhaul Aircraft Support Equipment	2
8	Repair/Charge/Decommission Aircraft/Support Equipment Batteries	2

SAMPLE

Classification UNCLAS

PART 1

FACILITIES REQUIREMENTS

Instructions: *List strategic functions from PART 2 and show in general terms all types of facilities required to accomplish this function. Include special requirements such as mechanical and electrical. Include all facilities even if not under control or responsibility of unit.*

FUNCTION FROM PART 2 (abbreviate but keep in same order as in Part 2)		FACILITIES AND UTILITIES TO ACCOMPLISH FUNCTION (express in general terms all types of facilities)	Existing Bldg No. If Applicable
No.	Action		
1	Repair Acft Avionics	8 Avionics Work Centers (requires 400 HZ Generators, 480/120 3ph electrical power air conditioning)	549
2	Repair Acft Structures/ Hydraulics/Wheels	10 Airframes shops (requires LP air, water 120/240 3ph electrical power, paint spray booth, Hydraulic clean room, plating room)	47 Bent 1-8
3	Repair Acft Power Plants	6 Work Centers (requires 4 overhead cranes, 2 degreasing tanks, prop control test stand and remote site engine test facility)	47 Ben 16-23
4	Repair Aircrew Survival Equipment	5 Work Centers (requires 240V 3ph electrical power, carbon dioxide storage facility)	256
5	Repair Acft Armament Equipment	3 Work Centers (requires L.P. air)	46 Bent 6-7 Ben 10-14
6	Calibration/Repair Acft Test Equipment	One Work Center (requires 400HZ electrical, L.P. air, air conditioning)	549
7	Repair/Issue Acft Support Equipment	6 Work Centers (requires L.P. air, 440V 3ph electrical, paint spray booth, water)	142, 134, 483, 541
8	Battery Maintenance	2 Work Centers (requires water and air conditioning)	575

SAMPLE

CLASSIFICATION UNCLASSIFIED

LIST OF FACILITIES PRESENTLY OCCUPIED

BUILDING NUMBER	TYPE OF FUNCTION PERFORMED IN BUILDING	SPECIAL REQUIREMENTS	FACILITY TYPE	IN EMERGENCY CAN FUNCTION BE RELOCATED? TO WHERE?	DOES BACKUP ALREADY EXIST? WHERE?
142	Support Equipment Repair	Electric-110,220; Compressed Air	4	Yes-any space	No
134	Support Equipment Storage	None	5	Yes-Bld. 225	Yes-Bld. 22[illegible]
483	Support Equipment Painting/Welding	Electric-110; Air; Paint Booth	4	Yes-Bld. 225	Yes-Bld 225
541	Support Equipment Training	None	5	Yes-any classroom	Yes-any classroom
549	Avionics Repair	Electric-400Hz; Compressed Air	3	50%-vans NAMTRADET	Yes-vans NAMTRADET
47	Power Plants	Overhead Crane; Compressed Air	3	Yes-unk	No
47	Airframes	Hydraulic Clean Room; Water	3	75%-ink	No
46	Armanent Repair	None	3	Yes-unk	No

--SAMPLE--

Classification ______________________________

TACTICAL/STRATEGIC FACILITIES

INVESTIGATION SURVEY

Organization ______________________________

Contact ______________________________

Phone ______________________________

Address ______________________________

____

____

____

If Tenant Activity ______________________________
Give Host Base

CLASSIFICATION ____________ PART 1

ORGANIZATION ____________

A. GENERAL MISSION STATEMENT

INSTRUCTIONS: *Write general mission statement of unit. Include any special mission requirements not included in the general mission statement for peacetime, contingency or disaster recovery missions.*

B. TACTICAL/STRATEGIC MISSION ELEMENTS

INSTRUCTIONS: *Write Tactical/Strategic mission elements in detail. Relate to readiness condition by placing check in box if performed in that condition. Do not include nonstrategic elements of mission.*

	TACTICAL/STRATEGIC MISSION ELEMENT	READINESS CONDITION				
NUMBER	Description	5	4	3	2	1

TACTICAL/STRATEGIC MISSION ELEMENT		Readiness Condition				
No.	Description	5	4	3	2	1

Classification ______________________ PART 2

FUNCTIONAL BREAKDOWN OF TACTICAL/STRATEGIC MISSION ELEMENTS

Instructions: *Provide detailed breakdown of strategic mission elements in Part 1B in terms of specific functions that must be accomplished by your unit. Include service support to your unit essential to accomplish mission.*

SPECIFIC FUNCTION		Element No. From Part 1B
No.	Action	

Classification ______________________________ PART 2 (continued)

SPECIFIC FUNCTION		Element No. From Part 1B
No.	Action	

Classification ______________________

FACILITIES REQUIREMENTS

Instructions: *List strategic functions from PART 2 and show in general terms all types of facilities required to accomplish this function. Include special requirements such as mechanical and electrical. Include all facilities even if not under control or responsibility of unit.*

FUNCTION FROM PART 2 (abbreviate but keep in same order as in Part 2)		FACILITIES AND UTILITIES TO ACCOMPLISH FUNCTION (express in general terms all types of facilities)	Existing Bldg No. If Applicable
No.	Action		

Classification ____________________

PART 3 (continued)

FUNCTION FROM PART 2 (abbreviate but keep in same order as in Part 2)		FACILITIES AND UTILITIES TO ACCOMPLISH FUNCTION (express in general terms all types of facilities)	Existing Bldg No. If Applicable
No.	Action		

CLASSIFICATION ____________

LIST OF FACILITIES PRESENTLY OCCUPIED

BUILDING NUMBER	TYPE OF FUNCTION PERFORMED IN BUILDING	SPECIAL REQUIREMENTS	FACILITY TYPE	IN EMERGENCY CAN FUNCTION BE RELOCATED? TO WHERE?	DOES BACKUP ALREADY EXIST? WHERE?

CLASSIFICATION________________________

2 Mission Essential Structure providing DIRECT support to military mission and MUST FUNCTION after an earthquake to meet mission requirements.

BUILDING____________________ NAS MOFFETT FIELD

OCCUPANT ORGANIZATION____

A) Mission Essential Task Being Performed In Building ?

B) Can this task be interrupted? If so how long?________________

C) Special Requirements
Electrical Power 120v____________
Electrical Power Other____________
Air Conditioning____________
Water____________
Compressed Air____________
Telephone____________
Communication____________
Shock Isolation of Equipment____________
Security____________
Other, Explain____________

D) Does backup exist for any items in C above?____________

E) Can this task be performed at another location on base? Describe____________

F) If this building becomes inoperable from an earthquake, how will this task be accomplished? Can it be performed at another base? Do contingency plans exist?

CLASSIFICATION________ __

3 Building of high importance which shoul. . given attention to minimize damage. Mission related facilities pro... DIRECT support to military mission but are not required to be functional immediately after an earthqual

BUILDING___________ NAS MOFFETT FIELD

OCCUPANT ORGANIZATION______________________

A) Mission Related Task Being Performed In Building

____

____

____

____

____

B) Can this task be interrupted. If so how long.__________

____

____

____

C) Special Requirements

Electrical Power 120v__________

Electrical Power Other__________

Air Conditioning__________

Water__________

Compressed Air__________

Telephone__________

Communication__________

Shock Isolation of Equipment__________

Security__________

Other, Explain__________

D) Does backup exist for any items in C above__________

____

____

E) Can this task be performed at another location on base Describe__________

____

____

____

F) If this building becomes inoperable from an earthquake, how will this task be accomplished Can it be performed at another base Do contingency plans exist

____

____

____

____

____

____

____

____

____

INDIVIDUAL FACILITY WORKSHEET

Facility Number ________________

Facility Type __________________

Relocated from/to ______________

Damage Estimates

Level/Percent/Source _________/_________/_________
_________/_________/_________
_________/_________/_________

Probable Damage ____________________________________

Replacement Costs

Structural Replacement Cost ___________________________
Source ______________________
Contents/Systems Replacement Cost ____________________
Major Items ____________________________
____
____
____
____
____
____

TOTAL REPLACEMENT COST ________________________

TOTAL DAMAGE _____________________

Upgrading Costs

Structural Upgrading Costs __________________________
Source ______________________
Nonstructural Upgrading Costs _______________________
Source ______________________
Other Upgrading Costs (Item/Cost) ___________________
____
____
____
____

TOTAL UPGRADING COSTS ____________________

Relocation Costs

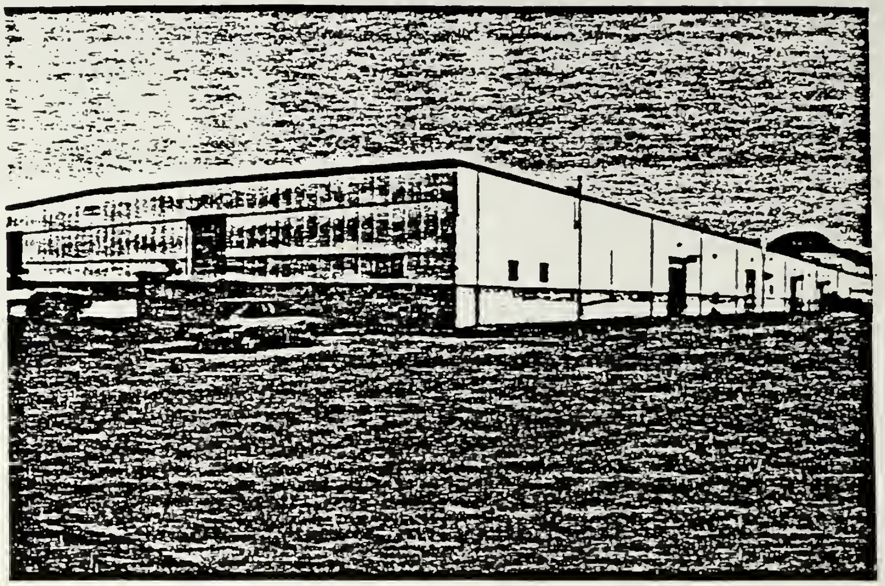
Relocation costs are to be included only at the alternate facility site.

Relocation Costs __________________________
Source _______________________

What Function is to be Relocated/From what Facility
____
____
____
____

APPENDIX B

PHASE I AND II FACILITY REPORTS



Building: 144 Warehouse

Description:

Year Built	- 1952		
Length	- 802 ft	Width	- 202 ft
Height	- 24 ft	No of Stories	- 1
Area	- 160,000 sq ft		

Construction:

Roof	- Metal deck on steel trusses
Exterior Walls	- Asbestos siding
Interior Walls	- Concrete
Columns	- Steel
Floors	- Slab-on-grade
Foundations	- Shallow spread footings

Building: 144 Warehouse

Lateral Resisting System:

Horizontal - Metal deck, steel X-bracing

Vertical - Steel X-bracing, concrete shear walls

Building Weight - 4,930 k   Volume - 3,700,000 cf

Unit Weight - 1.33 pcf

Ductility Factors
Longitudinal - 4.5   Transverse - 3.7

Original Base Shear Coefficient - 0.10 g

Comments:

Building consists of 4 bays separated by 3 concrete fire walls. The end walls have no lateral strength, thus for lateral forces, the end diaphragms cantilever off the first interior fire wall. This generates significant torsion. Damage is probably underestimated.

Recommendations:

RAPID ANALYSIS SUMMARY
DAMAGE ESTIMATE

BUILDING: 144 WAREHOUSE

BUILDING PROPERITIES:

	-TRANSVERSE DIRECTION- YIELD	ULTIMATE	-LONGITUDINAL DIRECTION- YIELD	ULTIMATE
PERIOD, SEC.	.04	.07	.73	1.22
DAMPING, %	.05	.10	.02	.05
STRUCT. CAPACITY, G.	1.29	1.64	.13	.21

BUILDING REPLACEMENT COST: $ 3198000.

DAMAGE ESTIMATES IN ACCORDANCE WITH CEL TM 51-78-02:

PK GRND ACCEL. G.	--TRANSVERSE DIRECTION-- SA SITE YIELD G.	DEMAND ULT. G.	DAMAGE %	--LONGITUDINAL DIRECTION-- SA SITE YIELD G.	DEMAND ULT. G.	DAMAGE %	COMBINED DAMAGE %	--TOTAL-- DAMAGE ESTIMATE 1000 $
.09-A	.09	.11	0.0	.20	.12	42.1	28.1	898
.25-B	.26	.30	0.0	.55	.32	100.0	66.7	2132
* .34	.36	.41	0.0	.75	.44	100.0	66.7	2132 *
.40-B	.42	.48	0.0	.88	.52	100.0	66.7	2132

A - SIMILAR TO U.B.C. CODE LEVEL FORCE
B - SENSITIVITY CHECK
*****
.34 = ACTUAL PGA SPECIFIED IN SCOPE, 80% PROBABILITY OF NOT BEING
***** EXCEEDED IN 50 YEARS.

EARTHQUAKE SAFETY INVESTIGATION SUMMARY OF NAVAL INSTALLATIONS

1.	ID	1				
2.	Installation	2	Naval Air Station - Moffett Field			
3.	Building Number	3	144			
4.	Use	4	Warehouse			
5.	Year Built	5	1952			
6.	Type of Construction	6	Steel			
7.	Number of Stories	7	1			
	Dimensions:					
8.	Typical Story Height	8	24 ft	Exception	9	ft
9.	Total Height	10	24 ft			
10.	Length	11	802 ft	Width	12	202 ft
11.	Area	13	160,000 sq ft			
12.	Volume	14	3,700,000 cf	Unit wt.	15	1.33 pcf
13.	Construction:					
	Roof	16	Metal deck on steel trusses			
	Exterior Walls	17	Asbestos siding			
	Interior Walls	18	Concrete			
	Columns	19	Steel			
	Floors	20	Slab on grade			
	Foundations	21	Shallow spread footings			
19.	Lateral Force Resisting System:					
	Horizontal	22	Metal deck, steel x bracing			
	Vertical	23	Steel x bracing, concrete shear walls			
20.	ATC-3 Classification:					
	Structural System	24	Building frame			
	Vert. Seis. Resist Sys	25	Braced frame and shear walls - concrete			
21.	Orig. Design Base Shear Coef:	26	0.10 g			
22.	Base Shear Capacity:		R=5,			R=1.
	Yield Long	27	.13 g	Trans	28	1.29 g
	Ultimate Long	29	.21 g	Trans	30	1.64 g
23.	Natural Period (seconds):					
	Yield Long	31	.73 sec	Trans	32	.04 sec
	Ultimate Long	33	1.22 sec	Trans	34	.07 sec
24.	Damping:					
	Yield Long	35	~~2~~ 5 %	Trans	36	5 %
	Ultimate Long	37	~~5~~ 10 %	Trans	38	10 %
25.	Ductility Factor: Long	39	4.5	Trans	40	3.7
26.	Max. Ground Accel. at Site:	41	0.34 g			
27.	Base Shear Demand:					
	Yield Long	42	.75 g	Trans	43	.36 g
	Ultimate Long	44	.44 g	Trans	45	.41 g
28.	Damage Estimate:					
	Long	46	100 %	Trans	47	0.0 %
	Combined	48	66.7 %			
29.	Replacement Cost, Thousands:	49	$3,198	Date	50	June, 1982
	Damage Estimate, Thousands:	51	$2,132			
30.	Rapid Evaluation Study by:	52	RUTHERFORD & CHEKENE			
31.	Detailed Struct. Analysis by:	53	RUTHERFORD & CHEKENE			
32.	Comments:	54	Location of resisting elements creates torsion, damage is probably underestimated.			

EXECUTIVE SUMMARY OF BUILDING 144

This report describes the detailed seismic evaluation of structural and nonstructural elements, and describes a method of structural strengthening, for Building 144 at N.A.S. Moffett Field. Building 144, a Warehouse, consists of four adjacent structures separated from each other by concrete fire walls. The four structures are identical and consist of a steel framed roof on long span steel trusses. The trusses are supported by steel columns on spread footings. The structures were analyzed individually using the techniques given in the Evaluation Criteria in Section 1, Part B of this report.

The analysis of the structure indicates that the roof diaphragm and longitudinal steel K bracing are overstressed by Level 1 forces. The repair scheme proposed is to strengthen the roof diaphragm by adding a new horizontal truss at the bottom chord of the existing roof trusses, and by adding new K braces. The cost for the structural repair is approximately $1,300,000.

The nonstructural survey located many potential hazards. These include falling hazards from light fixtures and overturning hazards from the substantial number of storage racks. The cost for bracing these elements is approximately $110,000. Thus the total repair cost for structural and nonstructural elements is approximately $1,410,000.

DETAILED EVALUATION OF BUILDING 144

Description of Building

Building 144/Warehouse is located between McCord Avenue and Zook Road, just north of Walcott Road (see Figure 144-1), and was built in 1952. The building is one-story throughout, and has a floor area of 160,000 square feet. Refer to the photographs in Figure 144-2 and the sketch plan and isometric in Figures 144-3 and 144-4.

The roof of Building 144 is a metal deck on steel trusses; the columns are steel; the exterior walls are asbestos siding on steel channel girts; the floor is a concrete slab-on-grade; the foundations are shallow spread footings. The interior partitions are concrete walls. The lateral load resisting system consists of a metal deck diaphragm and K braced columns in the longitudinal direction, and concrete shear walls in the transverse direction. The building is laid out as four bays separated by three concrete fire walls. The end walls have no lateral load resisting system. Therefore, for lateral forces, the end diaphragms must cantilever off the first interior fire wall.

Drawings of Building 144 are available at the Naval Air Station Moffett Field.

The Navy has designated Mission Essential as the criteria for analyzing the earthquake vulnerability of Building 144.

Results of Rapid Analysis

The Rapid Analysis calculations for Building 144 predicted 0% damage in the transverse direction and 100% damage in the longitudinal direction for the peak ground acceleration specified for the site.

The combined damage prediction was 66.7%, with an estimated damage cost of $2,132,000. The damage predictions were judged to be underestimated because the Rapid Analysis method did not account for the significant torsion which can be generated by the cantilevered diaphragm system of the end bays under lateral forces.

Results of Detailed Evaluation

Building 144 was evaluated using the Basic Criteria described in Section 1, Part B of this report. The fundamental period of vibration was calculated by hand analysis. See Figure 144-9 for a summary of the results.

Many elements are overstressed by Level 1 forces. The roof diaphragm is overstressed in shear, also, the connection of the diaphragm to the concrete shear walls is inadequate at Level 1. The braces in the longitudinal direction are also overstressed by Level 1 forces. At the end bays, the chord members are not properly anchored.

Level 2 forces were not evaluated because of the extensive overstresses determined at Level 1.

Method of Strengthening

The repair scheme for Building 144 is to replace the roof diaphragm with new horizontal trusses below the bottom chord of the existing trusses spanning to new K braces in the exterior longitudinal walls. For transverse forces, the truss spans to either the existing concrete fire walls or new K braces in the end walls of the building. The new K braces require a substantial base connection to tie them to the exterior concrete foundation walls. Refer to Figures 144-5 through 144-8 for the extent of the repairs.

Alternate methods for repairing the roof diaphragm are possible if the specifics of the diaphragm construction and connection are known. The existing metal deck roof diaphragm could be used if the interconnection of the sheets is adequate, and if sufficient chords and collectors are provided. The drawings provide no information concerning this. Thus any alternative scheme is dependent on additional information available only by reviewing the existing construction and removing a section of roof. A second alternative would be to strengthen the members and connections of the horizontal bracing at the top chord of the truss. This would require adding members and connections in a very congested space. Thus, the repair scheme of new trusses at the lower chord was chosen for this analysis, because it is most practical for installation based on the currently available information.

The repaired structure was checked for Level 1 and Level 2 forces using the Basic Criteria described in Section 1, Part B of this report. See Figure 144-9 for a summary of the results of the analysis of the repaired structure. Care was taken so that the period of the new horizontal truss would be sufficiently different from the period of the new K braces to prevent resonance problems. The new compression members of the trusses and K braces were sized to prevent buckling under Level 2 forces. The existing roof framing is rigidly attached to the fire wall at one end, referred to here as the fixed end. At the other end, the free end, expansion is allowed for by providing longitudinally slotted holes in the truss base plate. Similar allowance for expansion should be provided in the new repairs. The new transverse truss should be added on the fixed side of the fire wall. At the free side, the connection of the longitudinal truss should allow expansion.

Results of Nonstructural Survey

The nonstructural element seismic protection field survey showed several potential hazards to life safety and to essential Navy functions in Building 144. These hazards include falling objects such as light fixtures, overturning elements such as storage shelves, and the danger of natural gas leaks or disruption of fire extinguisher system lines.

The field survey methodology includes a hazard rating from -9 to +8 for every element based on occupancy, element failure mode, support effectiveness, and essential function. A hazard rating of zero or less is intended to be acceptable. A hazard rating above zero is intended to designate elements which present a risk to life safety or to the Navy mission, or both.

The nonstructural field survey data for Building 144 is included in Volume 2 of the Detailed Analysis Report. The survey methodology is described in a separate report titled "Seismic Investigation of Nonstructural Elements, Survey Methodology."

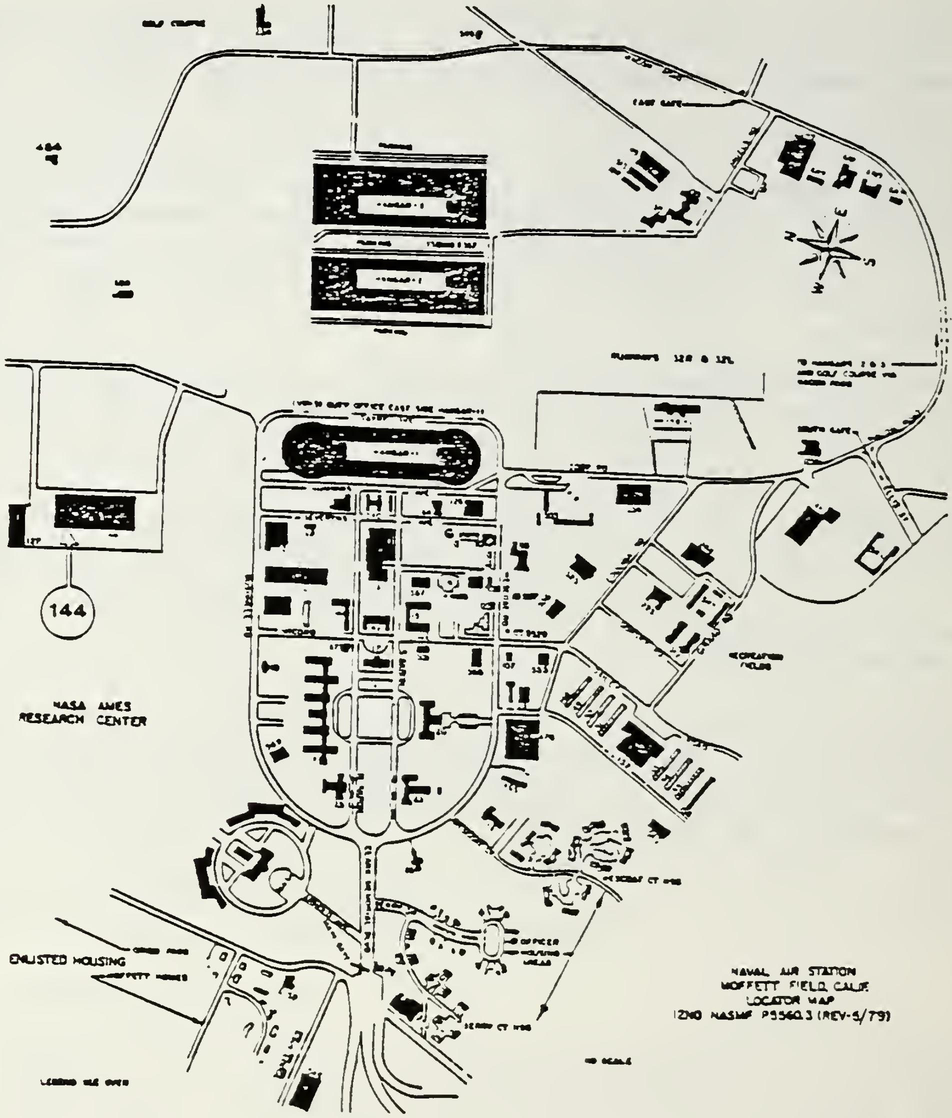
Estimated Repair Costs

The cost for implementing the structural strengthening scheme delineated in this report for Building 144 is approximately $1,300,000. The cost for retrofitting all potential nonstructural hazards is approximately $110,000. Thus the total cost for the repair of the structural and nonstructural hazards is approximately $1,410,000. This total cost is based on 1984 prices and does not include any factor for future escalation of prices.

The structural strengthening cost estimate for Building 144 is derived mostly from the anticipated cost of construction of a new horizontal diaphragm, which consists of five structural steel trusses. The estimated cost of 20 new K braces is also included.

As might be expected in a warehouse, nearly half of the nonstructural cost is estimated for bracing existing shelves and storage racks. The total nonstructural costs estimate will decrease from $110,000 if a higher level of risk is considered acceptable. For example, retrofitting only those elements with a hazard rating greater than 4 in either life safety or essential function, would eliminate about $10,000 from the estimate above. Retrofitting only life safety hazards rated above 4 would cost an estimated $60,000.

Since finishes were not removed during the walk-through evaluation, certain portions of the utility lines, such as the entrance to the building, could not be reviewed. The cost for any repairs required in the concealed spaces is not included in the above estimate. Thus the cost for a more detailed investigation and the repairs resulting would be in addition to the estimate above.

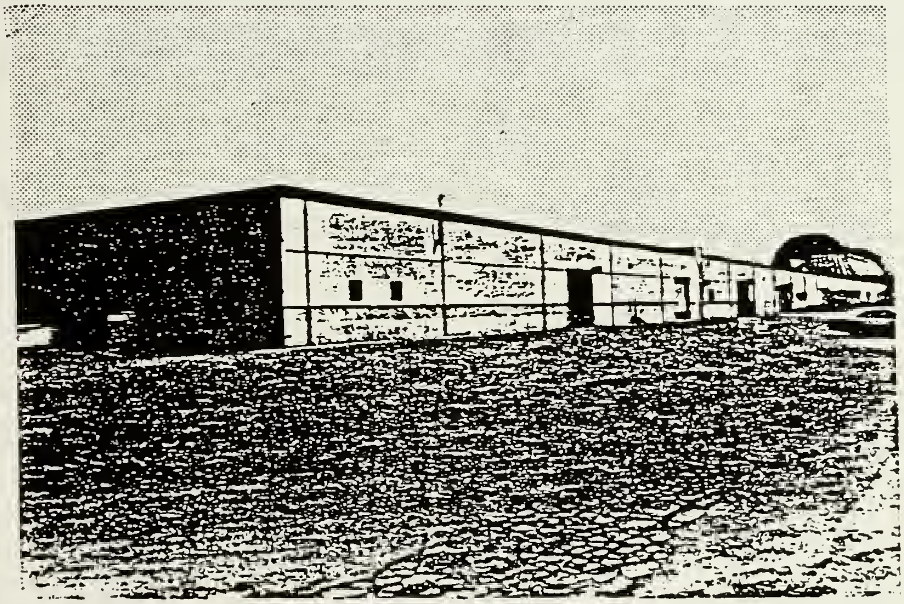


TITLE BUILDING LOCATION MAP

BLDG NO. 144	BLDG NAME WAREHOUSE	BY J.U.	FIGURE 144
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84	

RUTHERFORD & CHEKENE CONSULTING ENGINEERS 487 BRYANT STREET SAN FRANCISCO 94107 TEL 415/391-3990

WEST SIDE BUILDING 144 - WAREHOUSE



WEST SIDE

TITLE BUILDING PHOTOGRAPHS			
BLDG NO. 144	BLDG NAME WAREHOUSE	BY J.J.	FIGURE
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84	[illegible]

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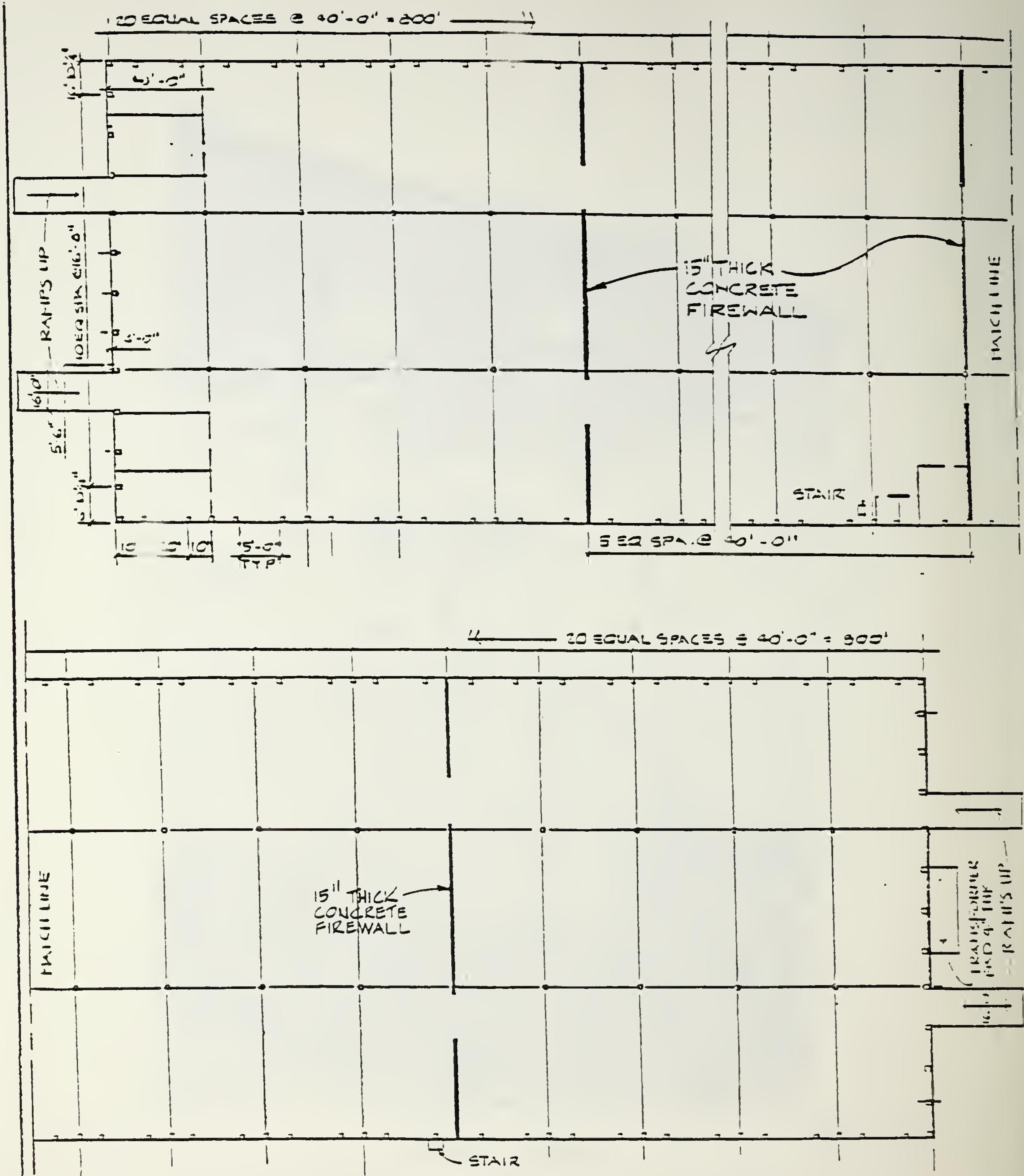

FIRST FLOOR PLAN A 144-3

TITLE FLOOR PLAN OF EXISTING STRUCTURE

BLDG NO. 144	BLDG NAME WAREHOUSE	BY VW	FIGURE 44-3
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84	

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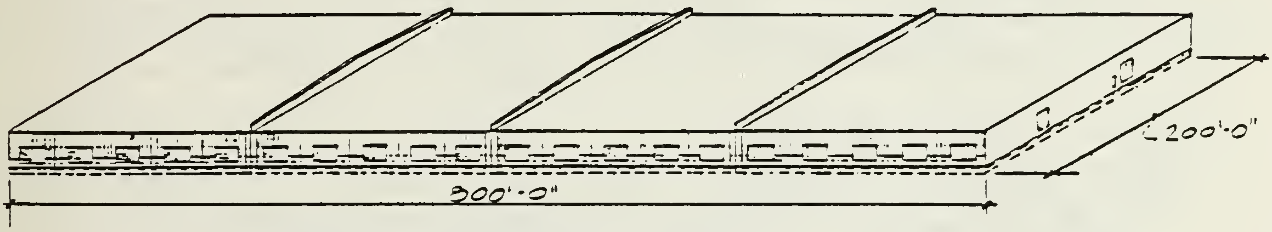
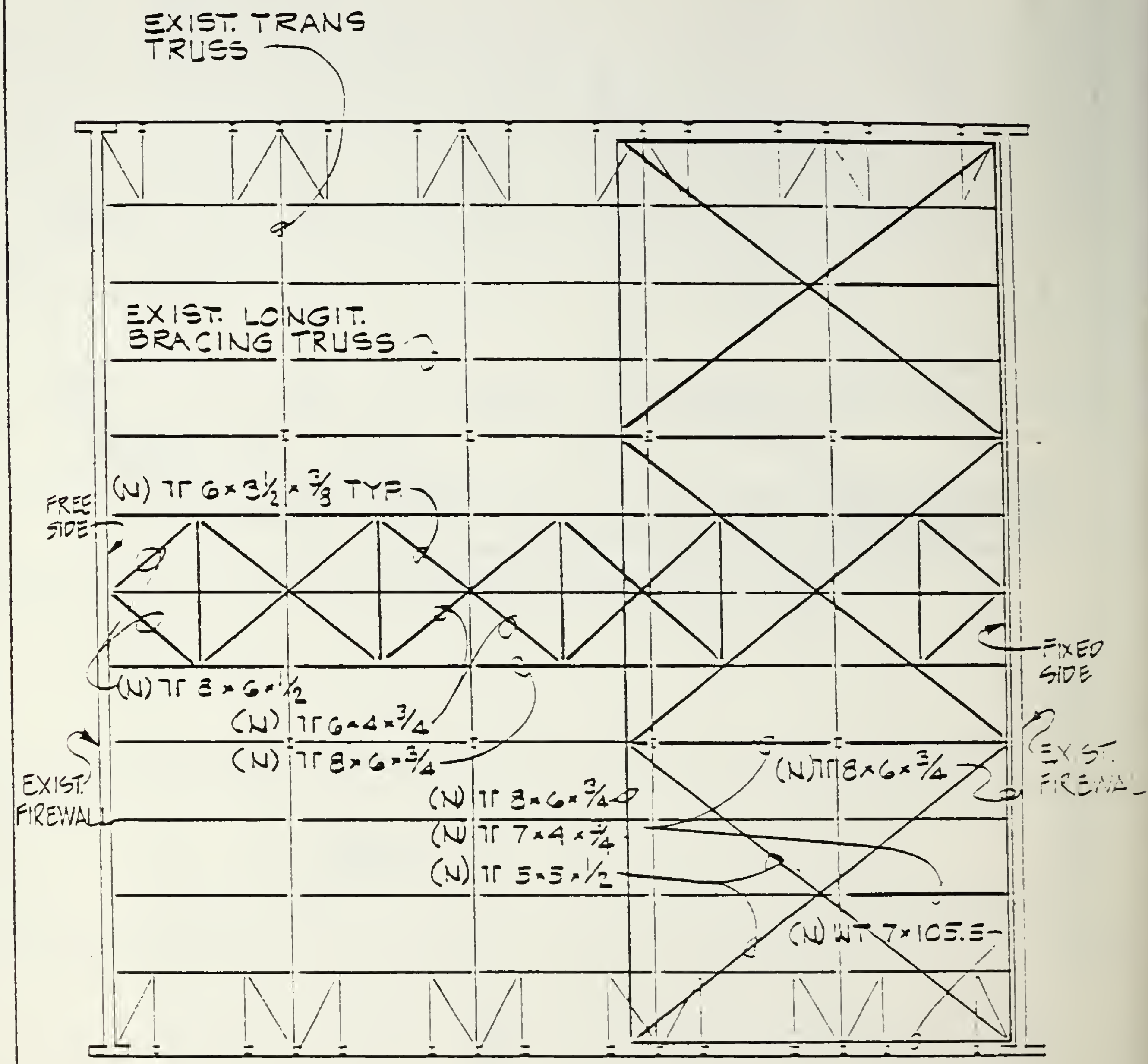


ELEVATION A 144-4 (ISOMETRIC)
SCALE: 1" = 100'-0"

TITLE ISOMETRIC OF EXISTING STRUCTURE			
BLDG NO. 144	BLDG NAME WAREHOUSE	BY J.U	FIGURE
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84	
RUTHERFORD & CHEKENE CONSULTING ENGINEERS 487 BRYANT STREET SAN FRANCISCO 94107 TEL 415/391-3990			

TRANSVERSE TRUSS MEMBERS AT BOTTOM CHORD OF INTERMEDIATE TRUSS.
LONGITUDINAL TRUSS MEMBER AT BOTTOM CHORD OF MAIN TRUSS.



PARTIAL ROOF PLAN A 144-5

TITLE PARTIAL ROOF PLAN OF REPAIRED STRUCTURE			
BLDG NO. 144	BLDG NAME WAREHOUSE	BY J.U.	FIGURE 44-5
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84	

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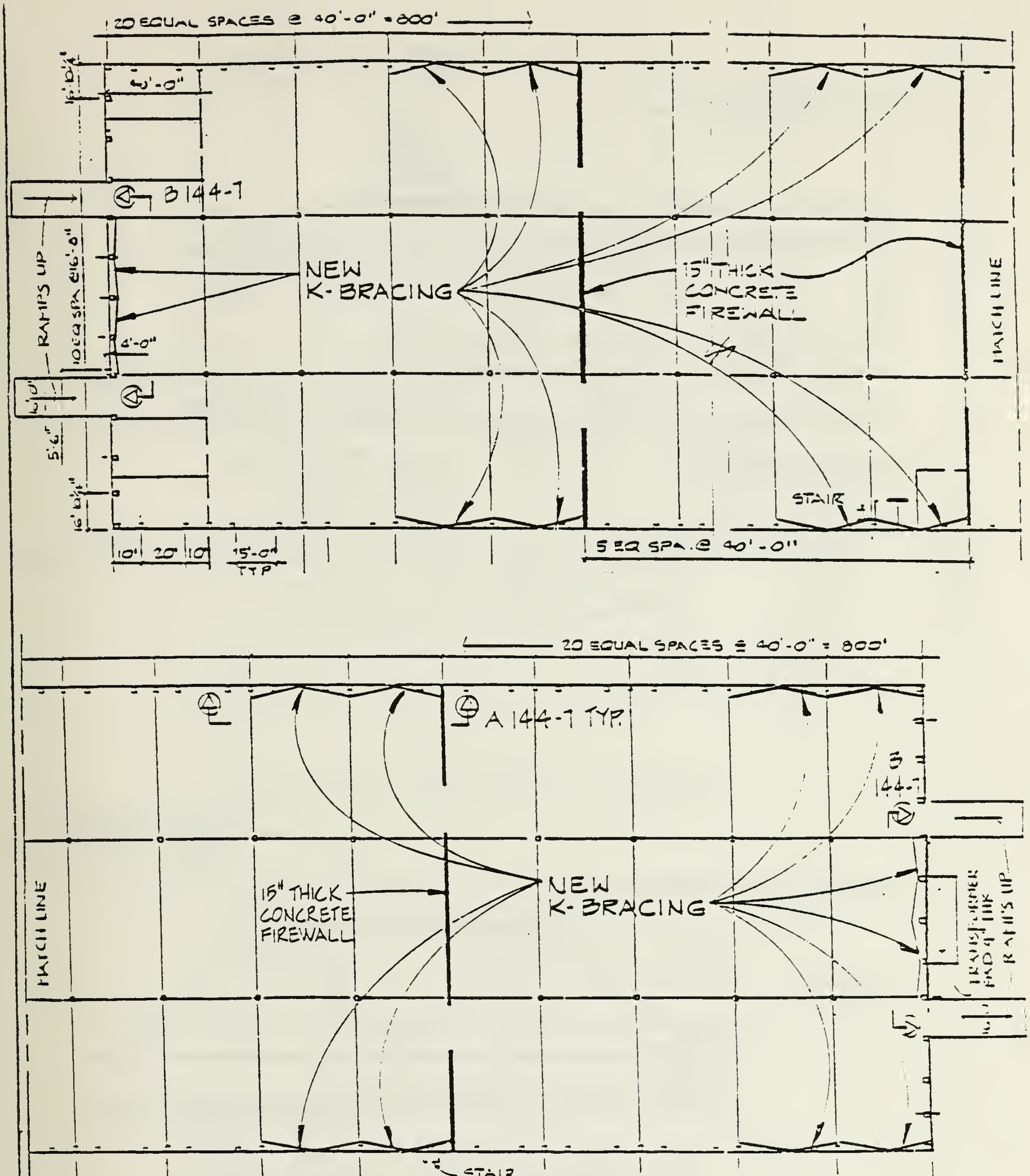

PLAN A 144-6

TITLE PLAN OF REPAIRED STRUCTURE			
BLDG NO. 144	BLDG NAME WAREHOUSE	BY J.U.	FIGURE 44-6
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84	

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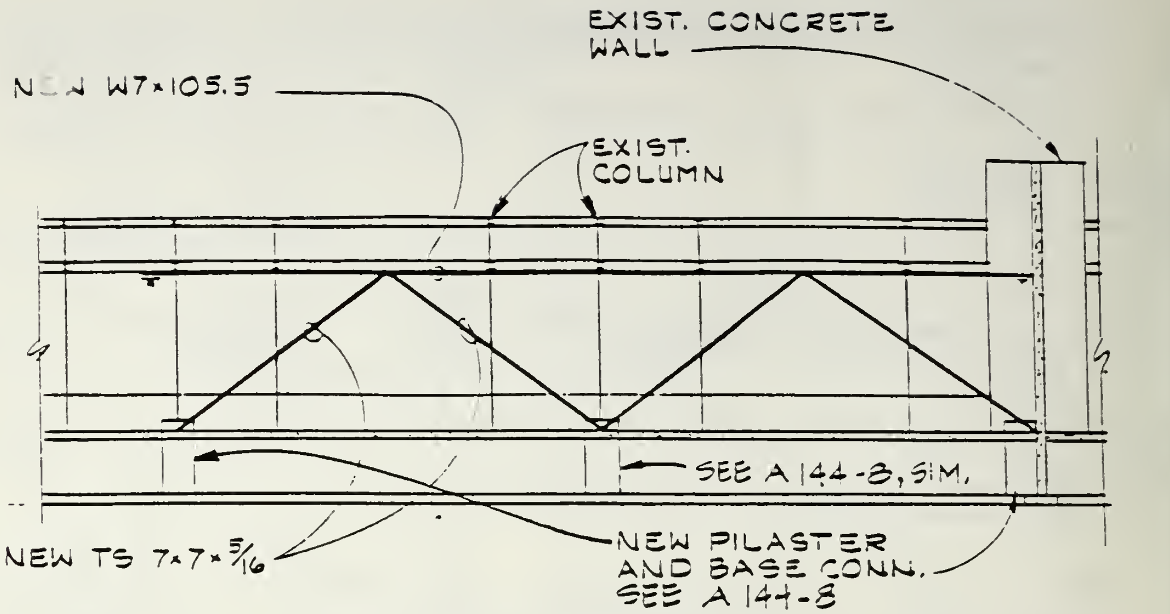
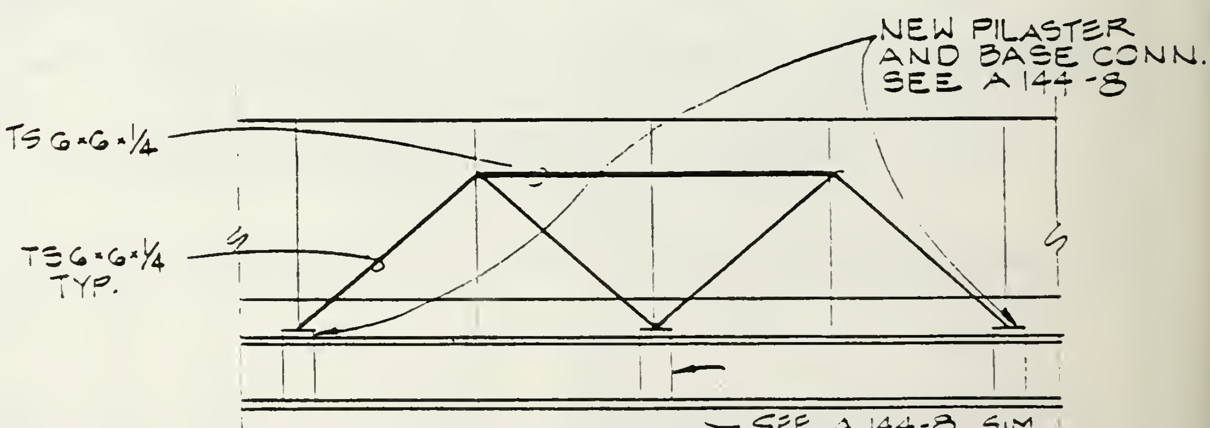


TYPICAL K-BRACE IN LONGITUDINAL WALL

ELEVATION A 144-7



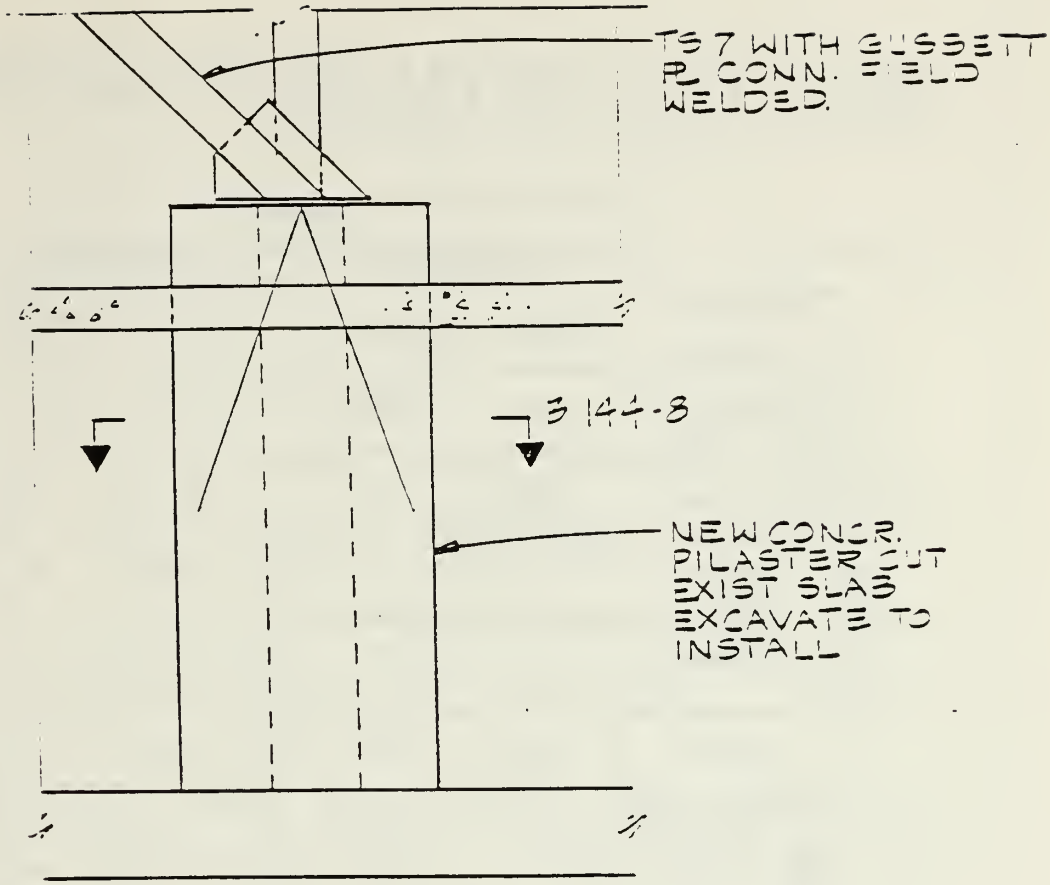
K-BRACE AT END WALL

ELEVATION B 144-7

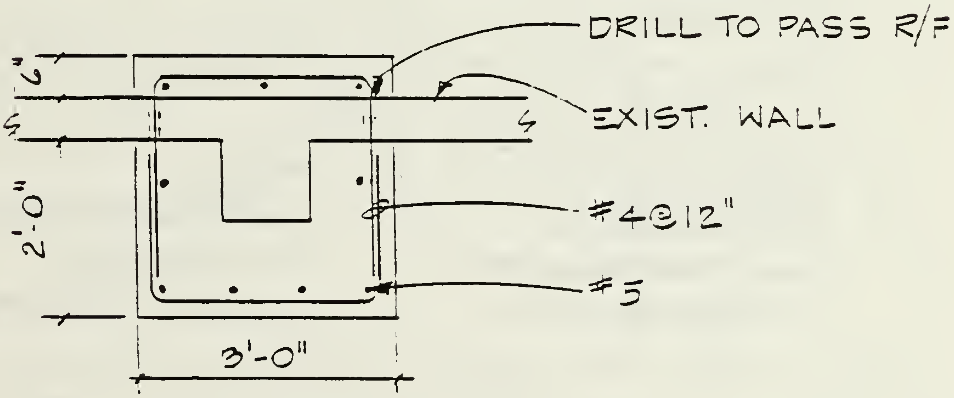
TITLE ELEVATIONS OF REPAIRED STRUCTURE		
BLDG NO. 144	BLDG NAME WAREHOUSE	BY J.U
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84

FIGURE 44-7

RUTHERFORD & CHEKENE CONSULTING ENGINEERS 487 BRYANT STREET SAN FRANCISCO 94107 TEL 415/391-3990



CONN @ BASE A 144-8



SECTION B 144-8

TITLE DETAILS OF REPAIRED STRUCTURE			
BLDG NO. 144	BLDG NAME WAREHOUSE	BY J.U.	FIGURE 44
EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD		DATE DEC 84	

RUTHERFORD & CHEKENE CONSULTING ENGINEERS 487 BRYANT STREET SAN FRANCISCO 94107 TEL 415/391-3990

RESULTS OF DETAILED EVALUATION

			DIRECTION			
			TRANSVERSE		LONGITUDINAL	
		STATE OF STRUCTURE	EXISTING	STRENGTH.	EXISTING	STRENGTH.
LEVEL 1	PERIOD	ANALYSIS TYPE	HAND	HAND	HAND	HAND
		T sec	.05	.32 *	.73	.24
		SPECTRAL ACCEL. g	.19	.41	.28	.40
		DAMPING %	5	5	5	5
		RESULTS	NG	OK	NG	OK
LEVEL 2	PERIOD	ANALYSIS TYPE		HAND		HAND
		T sec		.32		.24
		SPECTRAL ACCEL. g		.63		.63
		DAMPING %		10		10
		RESULTS	NC	OK	NC	OK

ANALYSIS TYPES

HAND: HAND ANALYSIS

COMP: COMPUTER ANALYSIS

EST: ESTIMATED RESULTS

RESULTS

NG: STRENGTHENING REQUIRED

OK: ACCEPTABLE

NC: CONDITION DOES NOT GOVERN

* PERIOD OF DIAPHRAGM

TITLE RESULTS OF DETAILED EVALUATION

BLDG NO. 144 | BLDG NAME WAREHOUSE | BY J.U. | FIGURE 112

EVALUATION OF SEISMIC VULNERABILITY OF STRUCTURES - NAS MOFFETT FIELD | DATE DEC 84

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APPENDIX C

NAVY EARTHQUAKE ADVISORY GROUP MODELS

The following models and descriptions are reproduced directly from Reference 21.

A. SEISMIC RISK MITIGATION MODEL

This section outlines the elements necessary to examine the relative effectiveness of improving different naval facilities on a given base to reduce the consequences of seismic risks. We would expect this model to be used only for facilities identified as (1) having relatively high risk from the Phase I information and (2) being relatively important in achieving the naval mission.

The discussion below developes the basic model which accounts for the possible loss of ability to perform the naval mission as a single objective. The use of such a model with hypothetical inputs is illustrated in section B. The model is extended to include objectives concerning possible fatalities and reconstruction costs in Section C. (All models discussed through Section C concern only one possible level of upgrade for each facility in order to focus on the concepts.) Section D indicates the how one would extend this to include an examination of different levels of upgrading for specific facilities and the decisions of which upgrade is most appropriate for a specific facility.

Before proceeding, several caveats seem appropriate. First, the model referred to here should only be a tool to aid decision makers, not a substitute for them. Second, the information required is not necessarily easy to obtain, but it appears to be essential to the problem. The level of complexity in the model is necessary to formalize the components of the problem that common sense tells us are important.

In the basic model the value of upgrading a particular facility (e.g., building, runway) should depend on four items:

1. The relative importance of the facility for performing the naval mission,
2. The probability of earthquakes affecting the usefulness of the facility,
3. The damage caused to the facility by an earthquake if the facility is upgraded, and
4. The damage caused to the facility by an earthquake if the facility is not upgraded.

To be more precise, the relative value of upgrading depends on the difference in damage to the facility caused by earthquakes of different magnitudes if it is or is not upgraded.

Let us assume that we wish to determine the relative importance of upgrading different facilities for the purpose of better performance of the naval mission. Then, the following model will address the items above with a level of sophistication appropriate for the quantity of data we could be expected to obtain. The relative value of upgrading facility "i", which will be written v(i), will be

$$v(i) = V_i \sum_m P_i(m)[d_0(i,m) - d_1(i,m)], \text{ all } i, \qquad (1)$$

where

V_i = the relative importance (i.e. value) of facility i to performing the naval mission,

$P_i(m)$ = the probability of an earthquake of Modified Mercalli Magnitude m over the expected lifetime of facility i,

$d_0(i,m)$ = the percent damage (meaning percent loss of usefulness for performing the naval mission) to facility i caused by a magnitude m earthquake if there is no upgrade of the facility, and

$d_1(i,m)$ = the percent damage to facility i caused by a magnitude m earthquake if the facility is upgraded.

Note that the term $[d_0(i,m - d_1(i,m)]$ indicates the percent reduction in damage to facility i caused by an earthquake of magnitude m if the facility is upgraded relative to when it is not upgraded. To use (1), it is necessary to determine V_i, $P_i(m)$, $d_0(i,m)$, and $d_1(i,m)$ for all relevant facilities i and magnitudes m at a given base. Some suggestions for this follow.

The V_i represent value judgements that would properly rest with the base commander. He or she may wish to delegate the authority for purposes of the model. To assess the V_i, ask first for a ranking of the relative significance of all of the facilities for performing the naval mission. There may be many facilities with equal significance. Then arbitrarily assign $V_i=10$ to the least significant facility. Then for facilities slightly higher in the ranking, determine by questioning how many times more significant they are than the least significant facility. If a facility is twice as significant, assign $V_i=20$ to it. Continue in this fashion comparing non-rated facilities to previously rated ones.

To determine $P_i(m)$ requires professional judgements from individuals knowledgeable about earthquakes and their effects. If all the ground at a base was exposed to the same seismic risks, then $P_i(m)$ would involve the same base rate for all facilities per unit time. One may, for example, assume a Poisson model for earthquake occurance, and calculate the probability of a magnitude m event per year for each magnitude. From this and the expected remaining lifetime of the facility, one could calculate

$P_i(m)$. Note that $P_i(0)$ would be the probability of no earthquake affecting the facility i during its lifetime.

The damage estimates $d_0(i,m)$ and $d_1(i,m)$ would depend on professional judgements of two types. One type would concern the impairment of facility i when subjected to a magnitude m under conditions of upgrade and no upgrade. The other type would concern the ability to perform the naval mission with such impairment. The estimates would necessarily be generated from discussions with the individuals having such expertise. In making these damage estimates, the amount of time the facility would be in a damaged state before significant repair returns the facility to operating condition might be accounted for by adjusting upward the damage estimate.

After the information necessary is obtained and processed using (1), the result is a set of numbers v(1), v(2), and so on. If v(1) is greater than v(2), then the relative value of upgrading facility 1 is greater than the relative value of upgrading facility 2. But this alone does not mean that it is more effective to upgrade facility 1. The difference is that it may be far more expensive to upgrade facility 1 than facility 2. We can calculate the relative effectiveness E_i of upgrading facility i using

$$E_i = \frac{v(i)}{\$(i)} \tag{2}$$

where \$(i) is the cost of upgrading facility i. The larger the effectiveness E_i, the more cost-effective it would be to upgrade facility i. Given a specific budget for upgrading facilities, one should upgrade facilities with the highest E_i and continue until the funds are allocated.

B. ILLUSTRATIVE EXAMPLE OF THE BASIC MODEL

This section illustrates how one would use the basic model outlines above. The example uses a set of fictious numbers that are, however, internally consistent.

Suppose we have four facilities: 1=runway, 2=fuel depot, 3=support facilities, 4=mess hall. The relative values are assumed to be $V_1 = 200$, $V_2 = 60$, $V_3 = 30$, $V_4 = 10$. The expected remaining lifetimes of the facilities are 20, 5, 10 and 10 respectively.

All the facilities are subject to identical seismic risks. No magnitudes under 4 will cause any damage and the probabilities of earthquakes of magnitudes 5, 6 and 7 occuring in a five-year period are estimated to be 0.10, 0.006, and 0.02 respectively. An earthquake of magnitude 8 or greater is extremely unlikely. Using the Poisson model, we would obtain the $P_i(m)$ shown in Table VIII (Note: these figures are hypothetical but are fairly consistent with the base rates for magnitudes).

TABLE VIII

Calculated $P_i(m)$

		Facility			
		1	2	3	4
	5	0.06	0.10	0.19	0.19
Intensity	6	0.20	0.06	0.11	0.11
	7	0.07	0.02	0.04	0.04

Next, we need to determine the damage estimates recognizing that this refers to the degree to which the naval mission is impared. The required information might be illustrated as shown in Table IX This indicates, for insistance, that the percent damage to the runway (facility 1) due to an Intensity IX event is 20% if upgraded and 30% if not upgraded.

TABLE IX

Damage Estimates $d_0(i,m)$ and $d_1(i,m)$

	Facility 1		Facility 2		Facility 3		Facility 4	
	Upgrade	None	Upgrade	None	Upgrade	None	Upgrade	None
magnitude 5	10	10	5	10	0	0	0	0
6	20	30	10	20	0	20	0	10
7	60	80	20	30	20	50	0	30

The next step is to substitute information in Tables VIII and IX into (1) and calculate the v(i). For instance

$$v(1)= 200[0.36(10-10) + 0.2(30-20) + 0.07(80-60)] = 680 \quad (3)$$

Similar calculations yield

$$v(2) = 78,\ v(3) = 102,\ \text{and}\ v(4) = 33. \quad (4)$$

Note that v(1) is large both because the relative value of the runway (V_1 =200) is greatest and because its lifetime is greatest (i.e, 20 years) so the probably that it will be subject to earthquakes is larger. The changes in the percent impairment due to earthquakes if an upgrade is undertaken is greater that the facility 1 for both facilities 3 and 4.

Suppose the costs of upgrading the facilities are respectively $\$_1$ =1.0, $\$_2$ =0.4, $\$_3$ =0.2, $\$_4$ =0.1 in millions of dollars. Then using (2), (3), and (4), we find the relative effectiveness of the respective upgrades are

$$E_1 = 680/1.0 = 680,$$
$$E_2 = 78/0.4 = 195,$$
$$E_3 = 102/0.2 = 510,$$
$$E_4 = 33/0.1 = 333. \quad (5)$$

Thus, available funds should first be spent on facility 1, then facilities 3, 4, and 2 in that order.

C. EXTENDED MODEL INCLUDING FATALITIES AND RECONSTRUCTION COSTS

Possible fatalities and reconstruction costs are considerations that can be accounted for with expressions similar to (1). Specifically, the expected number f(i) of fatalities saved by an upgrade to facility i is

$$f(i) = \sum P_i(m)[f_0(i,m) - f_1(i,m)], \quad (6)$$

where $f_0(i,m)$ is the expected number of fatalities at facility i induced by an earthquake of magnitude m if the facility is not upgraded and $f_1(i,m)$ is the expected number of fatalities when it is upgraded. Similarly, the expected cost c(i) saved by an upgrade to facility i is:

$$c(i) = \sum P_i(m)[c_0(i,m) - c_1(i,m)], \qquad (7)$$

where $c_0(i,m)$ and $c_1(i,m)$ are, respectively, the expected reconstruction costs due to a magnitude m earthquake when facility i is not and is upgraded.

To determine the relative importance I(i) of upgrading facility i including impact on naval mission performance, possible fatalities, and reconstruction costs, we calculate

$$I(i) = v(i) + k_f f(i) + k_c c(i), \qquad (8)$$

where k_f and k_c are scaling constants based on value judgements of the commanding officer. They indicate the importance of fatalities and reconstruction costs relative to mission performance.

Then similar to (2), the overall effectiveness E'_i of upgrading facility i is

$$E'_i = \frac{I(i)}{\$(i)} \qquad (9)$$

Funds should be invested in projects to maximize effectiveness when all three objectives are relevant.

D. EXTENDED MODEL ADDRESSING DIFFERENT LEVELS OF UPGRADING

It is straightforward to compare more than one possible level of upgrade for a particular facility using the methodology outlined above. First, equation (1) must be used to calculate the value of upgrading facility i to the new level. The only term in the equation that may change is $d_1(i,m)$, the percent damage to facility i caused by an intensity m earthquake if the facility is upgraded. The percent damage $d_0(i,m)$ given no upgrade, the probability

$P_i(m)$ of an earthquake of an intensity m over the life of the facility, and the relative importance V_i of the facility remain the same. Second, the dollar cost $\$(i)$ of upgrade must be changed in equation (2). Finally, to include possible fatalities and reconstruction costs, the terms $f_1(i,m)$ and $c_1(i,m)$ in equations (6) and (7) must be changed to include the expected number of fatalities and reconstruction costs with the new level of proposed upgrade.

To avoid ambiguity over notation, let us speak of upgrade level j to facility i. Then, corresponding to equation (1) the relative value of upgrade j to facility i, which will be written $v_j(i)$ will be

$$v_j(i) = V_i \sum P_i(m)[d_0(i,m) - d_j(i,m)] \qquad (10)$$

where $d_j(i,m)$ is the percent damage to facility i caused by a magnitude m earthquake if the facility is upgraded to level j. Then, corresponding to equation (2), the relative effectiveness E_{ij} of upgrade level j to facility i is

$$E_{ij} = \frac{v_j(i)}{\$_j(i)} \qquad (11)$$

where $\$_j(i)$ is the cost of upgrade level j to facility i. Analogous to equation (6), the expected number f (i) of fatalities saved by upgrade j to facility i is

$$f_j(i) = \sum P_i(m)[f_0(i,m)-f_1(i,m)], \qquad (12)$$

where $f_j(i,m)$ is the expected number of fatalities at facility i with upgrade j when an earthquake of magnitude m occurs. Similarly, the expected cost $c_j(i)$ saved by upgrade j to facility i is

$$c_j(i) = \sum P_i(m)[c_o(i,m) - c_j(i,m)], \qquad (13)$$

where $c_j(i,m)$ is the expected reconstruction costs due to a magnitude m earthquake when facility i receives upgrade j.

Taking equation (11) through (13) into account as in equation (8), the relative importance $I_j(i)$ of upgrade j to facility i including impact on naval mission, possible fatalities and reconstruction costs, we calculate

$$I_j(i) = v_j(i) + k_f f_j(i) + k_c c_j(i). \tag{14}$$

Finally, analogous to equation (9), the overall effectiveness of E of upgrade j at facility i is

$$E'_{ij} = \frac{I_j(i)}{\$_j(i)} \tag{15}$$

The expressions (11) and (15) can be used to compare different possible upgrades to a facility. In general, the higher the effectiveness, the more desirable the proposed upgrade. But this information does not tell all the story. It does not realistically compare the alternative of not to upgrade with different upgrade alternatives. (Mathematically, both the value and cost of no upgrade are zero so equation (11) would be meaningless since it would divide zero by zero in that case.) It also does not explicitly focus on the budget available for upgrading facilities, it rather suggests the most effective upgrades given a budget. In both of these situations, the decision makers would want to consider, at a minimum, the effectiveness and cost of each proposed upgrade level (including no upgrade) for each facility. A useful way to present this information might be in a matrix which specified the various facilities considered on the x-axis and the different levels of upgrade on the y-axis. In each cell one would present the relative importance of that upgrade $I_j(i)$, and the cost of the upgrade $\$_j(i)$. To complement each cell, a narrative description of the consequences to facility i given upgrade j under various earthquake intensities might be described. The decision on what to do with each facility should be taken using professional judgement and values to combine the relative importance and cost of each upgrade level, including the option of no upgrading, as well as the budget available.

APPENDIX D

EMERGENCY FACILITIES USE PLAN

The Emergency Facilities Use Plan is a by-product of the determination of the mission essential facilities process. During the investigation of the bases missions, possibly for the first time, the department heads/tenant commands were able to study their functions and possible options available to them after an earthquake. The identification of substitute facilities should not be lost or buried in a report, but should be promulgated. The collection of this information in a single source could be of great benefit to aid in disaster recovery. This section will highlight recommended items for inclusion in an Emergency Facilities Use Plan. The plan should be divided into three sections; the first concerning facilities, the second concerning functions, and the final on other concerns.

The portion of the plan concerning facilities should be a listing of the bases facilities with a description of its characteristics. As a minimum, the descriptions should include a section on the construction and size of the facility, simply for general information, along with the current use of the facility. facility and the major functional capabilities present in the facility. The major functional capabilities are akin to the missions being performed in the facility. Tied to these capabilities are the major equipment items present in the facility. The sizes or capabilities of the major equipment items should be noted. The plan is intended to be used in an emergency, having the capabilities of a piece of equipment in a facility handy can save valuable recovery time trying to determine these items. Identification of the utilities servicing the facility is also required. This is included to prevent possible overloading of the electrical service if equipment is relocated, etc. Finally, the possible alternative uses of the facility are addressed. Logical alternative uses keying on the basic needs and missions of the base should only be addressed. If a facility has a snack bar an alternative use could be as a galley. Tied to the capabilities of the major equipment items, an estimate of the feeding capacity of that facility can be easily obtained in an emergency. Facilities identified as being duplicate facilities or relocation sites for mission functions from the survey process should be identified as such in the plan. Examples of the facility characteristics are described in Table X.

The second section is on the functions. This section is simply a reorganization of the data to indicate where each function is and can be carried out. The functions should key on the basic needs of man and mission functions of the base. For each identified function the location where it is currently being carried out along with the capabilities of that facility are identified. Possible alternative sites are also identified but are clearly identified as requiring the relocation of some equipment or supplies to perform the function.

The final section is on other concerns. Included can be a plan for allocating transportation, based on possible requirements identified during the survey process. A mission function recovery priority based on the final facility type listing. Primary relocation sites for mission functions identifying the specific equipment, utilities or other needs required to relocate and resume the operation of the mission function. Descriptions of the process for relocation, prioritizeation of work, responsibilities, etc. All the other concerns should identify items raised during

TABLE X

Facility Characteristics

Facility Construction -wood, steel reinforced concrete, etc.

Size -square feet

Current Uses -office, hanger, gymnasium, etc.

Major Functional Capabilities -galley, snack bar, machine shop, message center, radio communications, secure telephone system, dispensary, cold storage, berthing, etc.

Major Equipment Items (Capabilities/Sizes)-cubic feet of cold storage; feeding capability of galley or snack bar, number of ranges, scuppers, etc.; equipment in machine shop, metal or wood lathes, hoists, drill presses, etc.; berthing capacity of berthing spaces, normal and under emergency conditions, number of mattresses, sheets, etc., washing machines, dryers; gasoline pumps and storage at gas stations; typewriters in office spaces, etc.

Utilities -electrical service, telephone service, water, sewage, dedicated telephone or communications lines, etc.

Alternative Uses of the Facility -gymnasium as berthing, first aid station, warehouse; snack bar as galley; commissary refrigerators as cold storage; auto hobby shop as an automobile and truck repair facility; etc.

the survey process. The Emergency Facility Use Plan is intended to be a document that can be consulted to allow a rapid recovery of mission functions. It is better to know that the feeding capacity of the clubs is sufficient to feed the base population in advance than to wonder when the galley is lost. Concentrating on the needs of man, the bases mission functions and issues raised during the survey process will provide a viable document for command decisions.

APPENDIX E

SEISMIC DAMAGE POTENTIAL MAP

The Seismic Damage Potential Map concept was proposed by the Navy Earthquake Risk Reduction Panel as a tool to highlight the seismic hazard potential at a particular base. The map uses information from the Phase I and II studies along with on-site engineering estimates, and a compilation of geotechnical information to highlight the facilities most subject to seismic damage. The basis of the map is the color coding of a standard "Base Development Map" to indicate the different facility types, building performance characteristics, and nonfacility seismic hazards. Through the use of overlays many different issues can be addressed. [Ref. 21]

A Seismic Damage Potential Map is developed as follows. First the basic Base Development Map is color coded by facility types. Each facility type is assigned a unique color and each facility in each facility type is color coded. For facility types 1 through 3 the individual facility or system should be identified, i.e. Building 144 or the telephone system. Where possible the most important mission functions should be identified.

Next, an overlay is prepared indicating the anticipated damage. The damage estimates from the Individual Facility Worksheet or Phase I study are to be used. The Panel recommended using the damage estimate related to "likely strong ground shaking" at the site, corresponding to approximatly Modified Mercalli Intensity VIII-IX or, for seismic zones 3 and 4, to about 0.3 to 0.5g. [Ref. 21]. The damage estimates are stated as the percent damage from the Individual Facility Worksheets are placed on the overlay corresponding to the base facilities.

Next any nonfacility seismic hazards are placed onto an overlay. Nonfacility hazards include areas subject to flooding, tsunami damage, soil liquefaction possible areas, landslide potential areas, etc. The nonfacility hazards use geologic data. Other overlays can illustrate active or known earth faults if they traverse the base. Fire sources and areas of fire spread can be identified on another overhead. If desired the building construction can be identified in basic terms and identified on an overhead. Such basic terms as; wood, steel, reinforced concrete, etc. are all that is required.

The purpose of the Seismic Damage Potential Map is to identify the important structures and the possibility of damage from seismic sources and consequences. Using these maps with their data presentation, a commander can begin to see critical and mission essential facilities which may be rendered inoperable in the event of a major earthquake affecting a base.

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